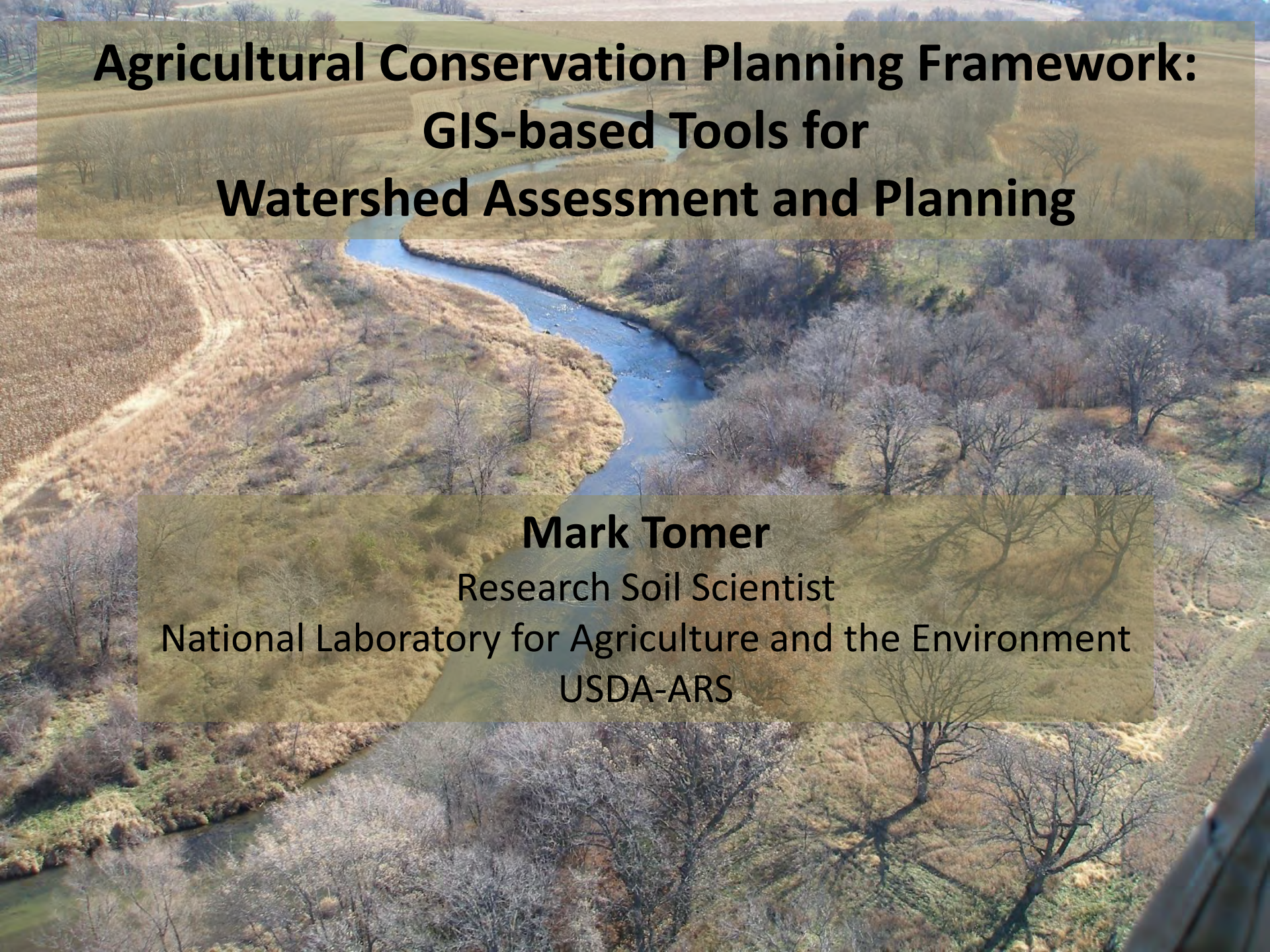
Agricultural Conservation Planning Framework: GIS-based Tools for Watershed Assessment and Planning



Mark Tomer
Research Soil Scientist
National Laboratory for Agriculture and the Environment
USDA-ARS

Outline

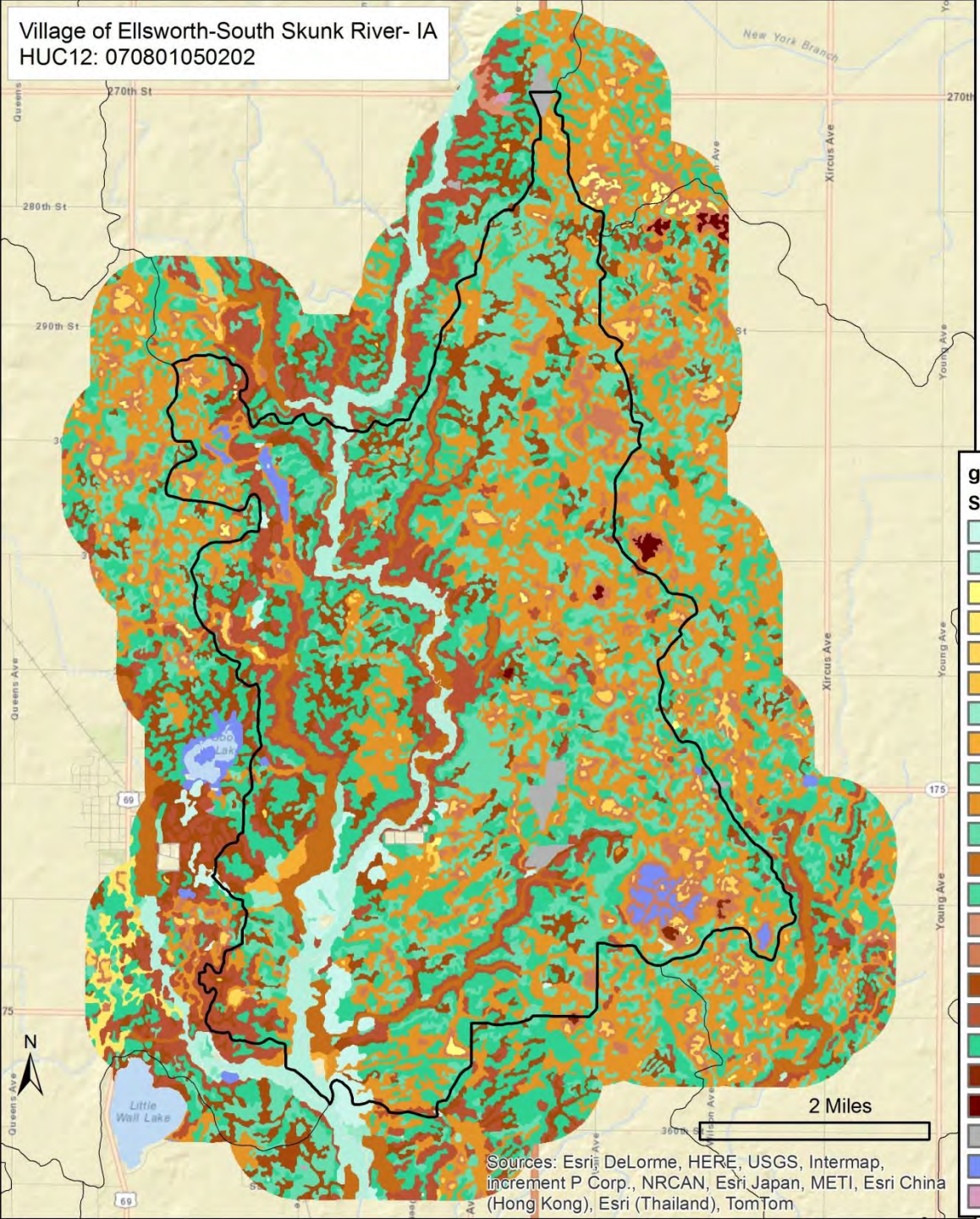
- The Agricultural Conservation Planning Database
- The Agricultural Conservation Planning Framework
- Example applications in **HUC12** watersheds (5000-16000 ha)
- Planning scenario development and nutrient reduction assessment (spreadsheet calculator)

New high resolution data sources are available for large areas across much of the central U.S. that could substantially enhance watershed planning capabilities.

Soils

Land use and crop rotations

Terrain



Soils Data

- gSSURGO 10m rasters
- MUAggAtt
- VALU1
- Horizon
- Texture
- Parent Material

gSSURGO

SurfHrz070801050202.TaxCls

- Coarse-loamy, mixed, superactive, mesic Typic Hapludolls
- CUMULIC HAPLUDOLLS, FINE-LOAMY, MIXED, MESIC
- Fine, smectitic, calcareous, mesic Cumulic Vertic Endoaquolls
- Fine, smectitic, calcareous, mesic Vertic Endoaquolls
- Fine, smectitic, mesic Cumulic Vertic Endoaquolls
- Fine-loamy over sandy or sandy-skeletal, mixed (calcareous), mesic Typic Endoaquolls
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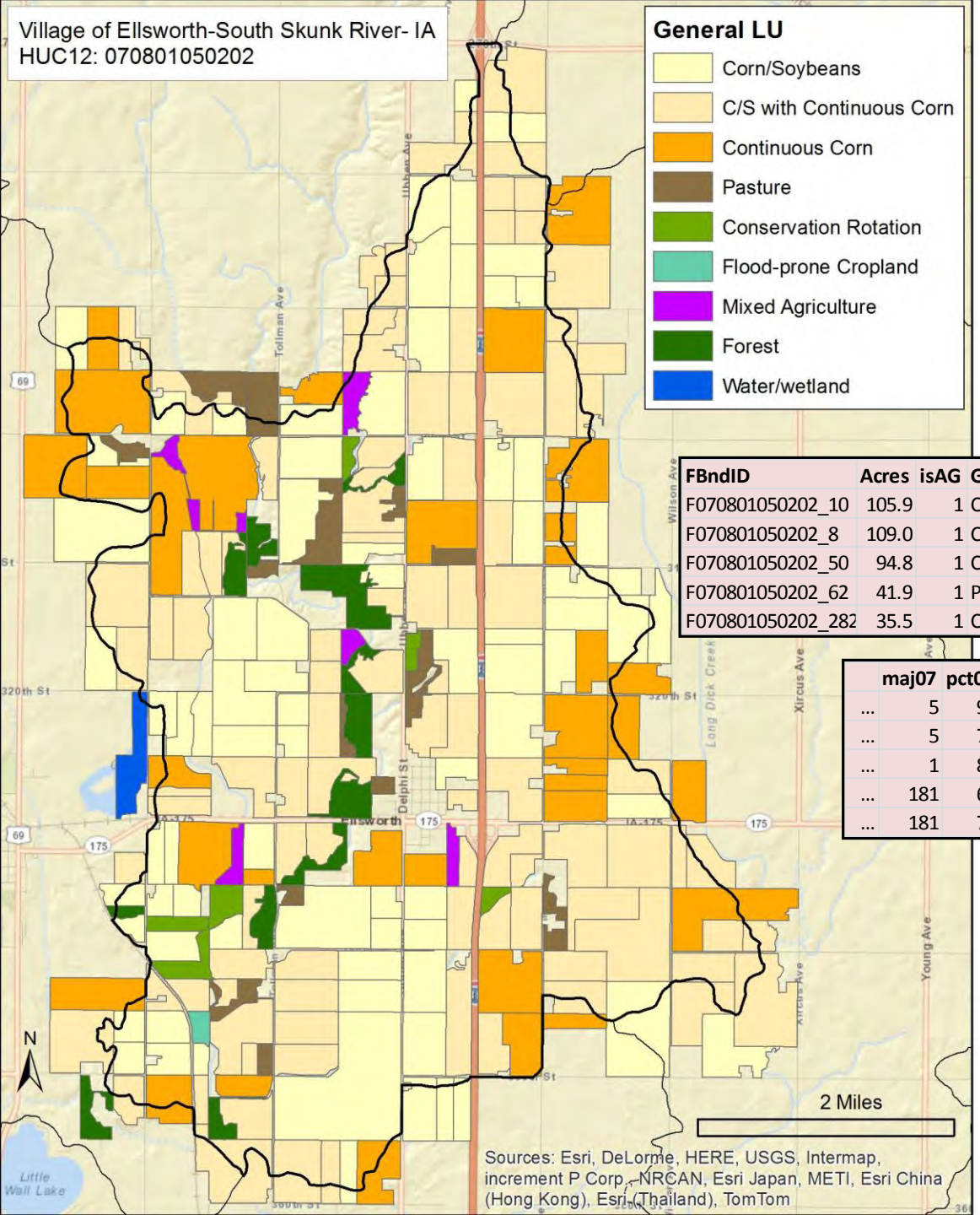
- Fine-loamy, mixed, superactive, mesic Glossic Hapludalfs
- Fine-loamy, mixed, superactive, mesic Typic Calciaquolls
- Fine-loamy, mixed, superactive, mesic Typic Endoaquolls
- Fine-loamy, mixed, superactive, mesic Typic Eutrudepts
- Fine-loamy, mixed, superactive, mesic Typic Hapludolls
- Fine-silty, mixed, superactive, calcareous, mesic Typic Endoaquolls
- Fine-silty, mixed, superactive, mesic Typic Endoaquolls
- Loamy Udorthents
- Loamy, mixed, euic, mesic Terric Haplosaprists
- TERRIC MEDISAPRISTS, LOAMY, MIXED, EUIC, MESIC

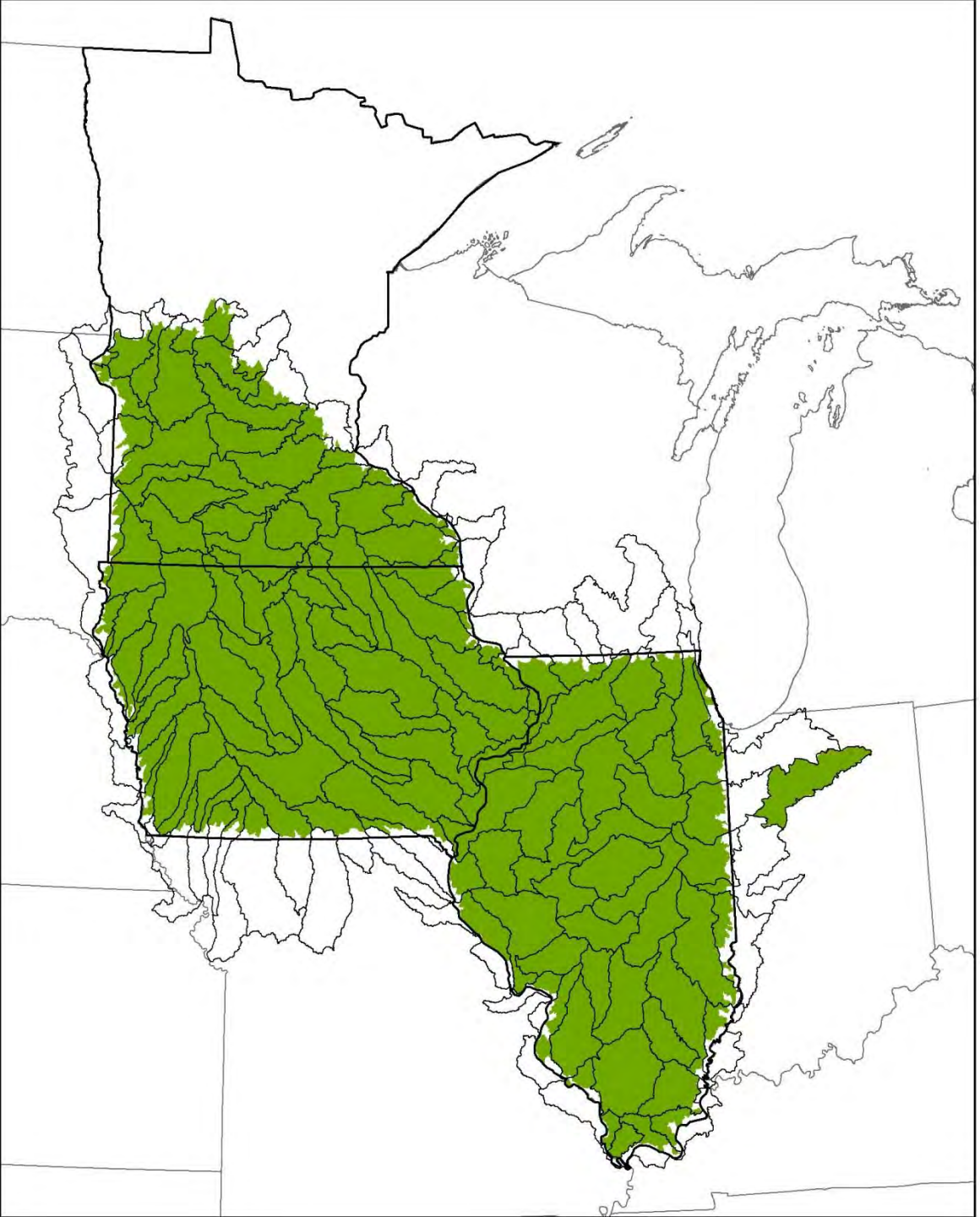


Land Use Data

- 2007-2012 NASS CDL
- Sequence of major crops
- Individual-field dominant crop
- Dominant crop percent of field
- Rule-based crop rotation
- Continuous corn count

FBndID	Acres	isAG	GenLU	CropRotatn	CropSumry	CCCount	MixCount
F070801050202_10	105.9	1	Corn/Soybeans	BCBCBC	C3B3	0:6	0:6
F070801050202_8	109.0	1	C/S with Continuous Corn	BCBCCC	C4B2	2:6	2:6
F070801050202_50	94.8	1	Continuous Corn	CCCCCC	C6	5:6	0:6
F070801050202_62	41.9	1	Pasture	PPPPPP	P6	0:6	6:6
F070801050202_282	35.5	1	Conservation Rotation	PPPCBC	C2B1P3	0:6	3:6

	maj07	pct07	maj08	pct08	maj09	pct09	maj10	pct10	maj11	pct11	maj12	pct12
...	5	94	1	93	5	92	1	94	5	93	1	99
...	5	74	1	82	5	74	1	91	1	82	1	91
...	1	84	1	93	1	84	1	96	1	97	1	99
...	181	68	181	66	181	45	181	51	171	43	171	74
...	181	74	181	32	181	46	1	76	5	80	1	87

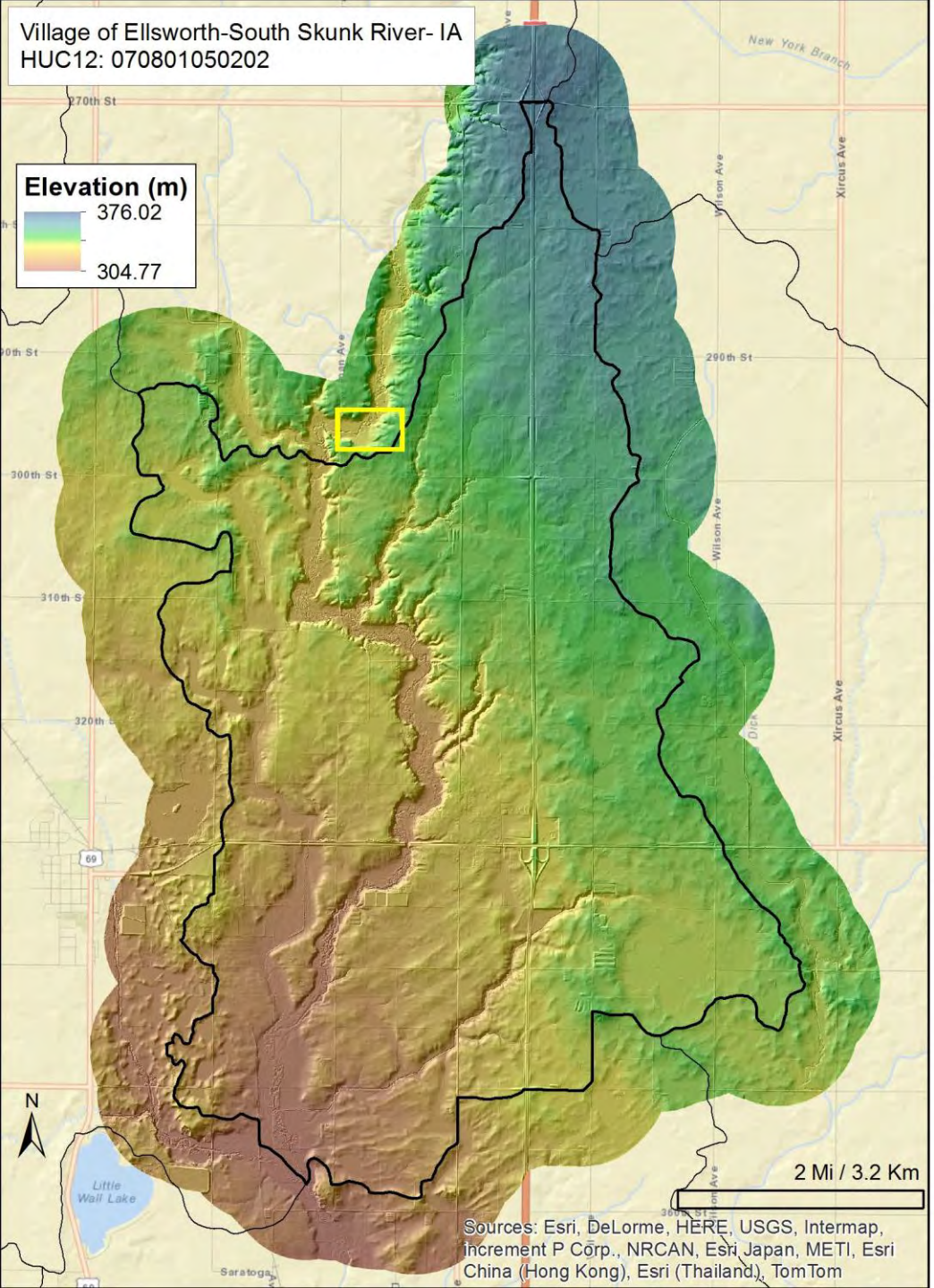


Agricultural Conservation Planning Database

- Three states: MN, IA, IL and some Indiana
- >4,200 HUC12 watersheds
- >35,000,000 ha

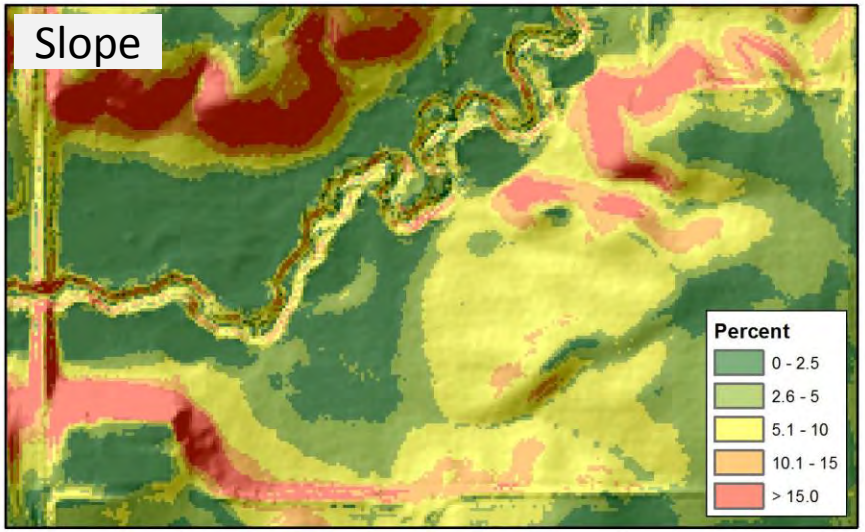
Major Geo-Spatial Components By HUC12

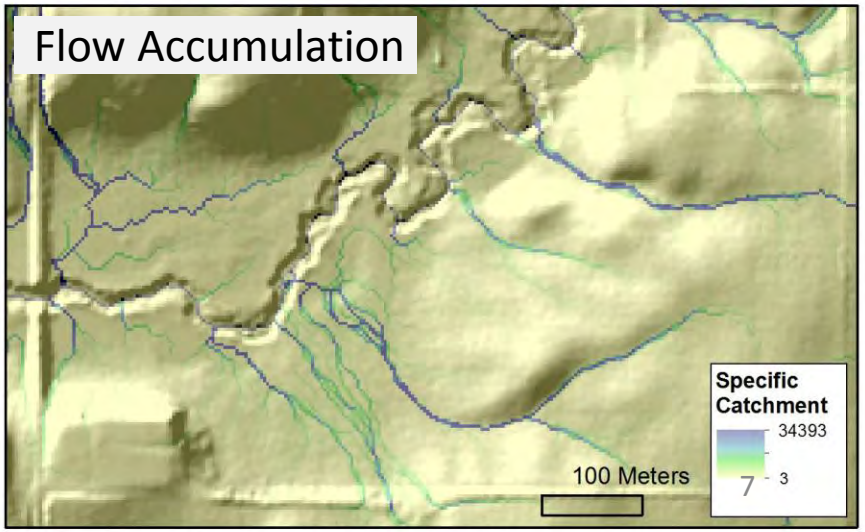
- gSSURGO – 10m raster
- NASS Crop Data Layer
  - 2000-2012
- LiDAR-based elevation
  - 3m resolution
  - Iowa
  - Minnesota
  - Indiana
- 2009 crop-specific field boundaries



Terrain Data

- LiDAR-derived digital elevation model
- 3m horizontal resolution
- Hydrologically enforced





Agricultural Conservation Planning Database Summary

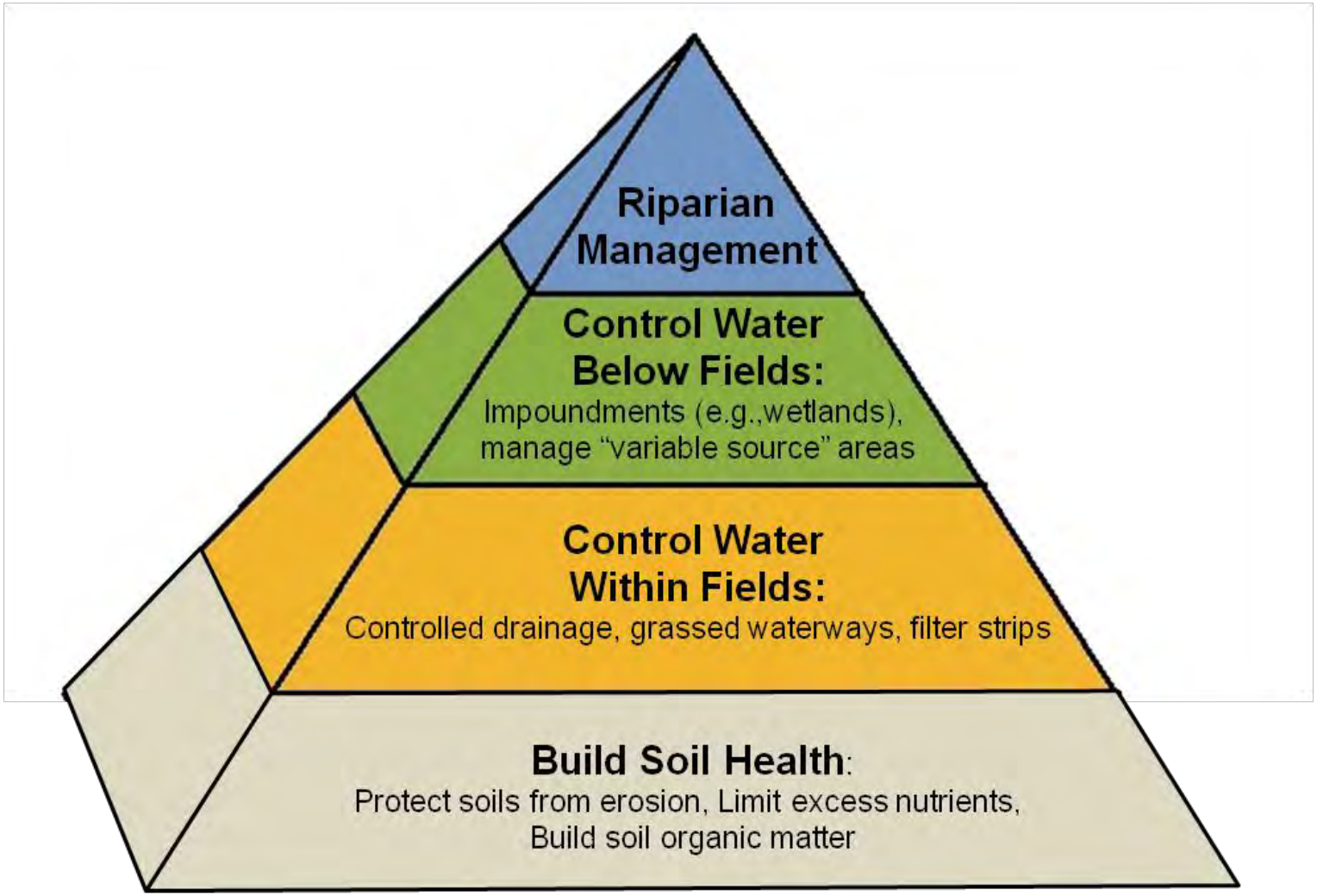
- High-resolution spatial data to assist agricultural conservation planning across a broad region that includes pertinent spatial data on:
  - Soils
  - Land Use
  - Terrain
- Enables analysis/evaluation at watershed and field scales
- Consistent structure allows conservation planning tools to be applied anywhere across the region.

How can we leverage these data and develop an approach to identify conservation alternatives for watersheds to achieve nutrient reduction goals and sustain agricultural production?

Any broad based approach to watershed planning must consider four needs:

- The need to recognize the uniqueness of each watershed;
- The need to recognize the independence of individual farmers and include them as equal partners in the planning process;
- The need to include a mix of practices placed within fields and below field edges in order to meet nutrient reduction goals; and,
- The need to protect and improve our soil resource to increase crop productivity and moderate hydrologic responses to extreme events.

Concept for Agricultural Conservation Planning Framework (ACPF): A CONSERVATION PYRAMID FOR AGRICULTURAL WATERSHEDS



Process for conservation planning to improve water quality in agricultural watersheds using precision technologies

DATA REQUIRED: LiDAR-based digital elevation model, Soil survey, Field boundaries, Land use

AVOID and CONTROL : Improve soil health within cropped fields to avoid and control pollutant losses by-
Protecting soils from erosion with zero or minimum tillage;
Limiting excess nutrients through rates and timing of fertilizer and manure applications;
Building soil organic matter and rejuvenating compacted soils with intensified crop rotations

CONTROL, TRAP, and/or TREAT

IN FIELDS:
Place water control / filter practices

BELOW FIELDS
Place water detention / nutrient removal practices

RIPARIAN ZONE
Place/design practices for ecosystem function and nutrient removal

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CONTROL, TRAP, and/or TREAT	TILE DRAINAGE	SURFACE RUNOFF
IN FIELDS: Place water control / filter practices		
BELOW FIELDS Place water detention / nutrient removal practices		
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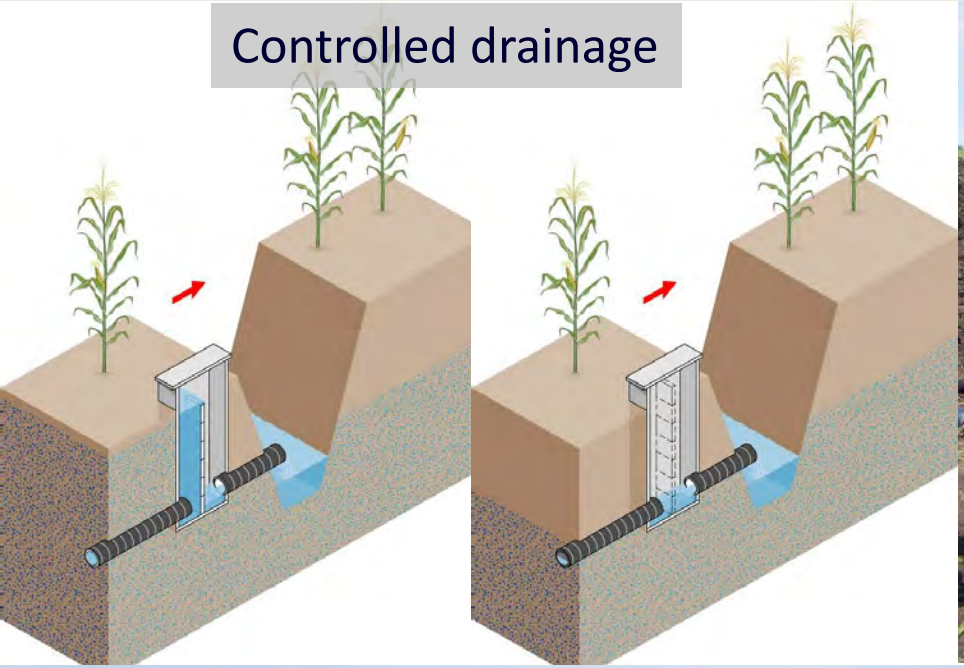
Practices for Reducing Nitrate Loads from Tile Drainage

Controlled drainage



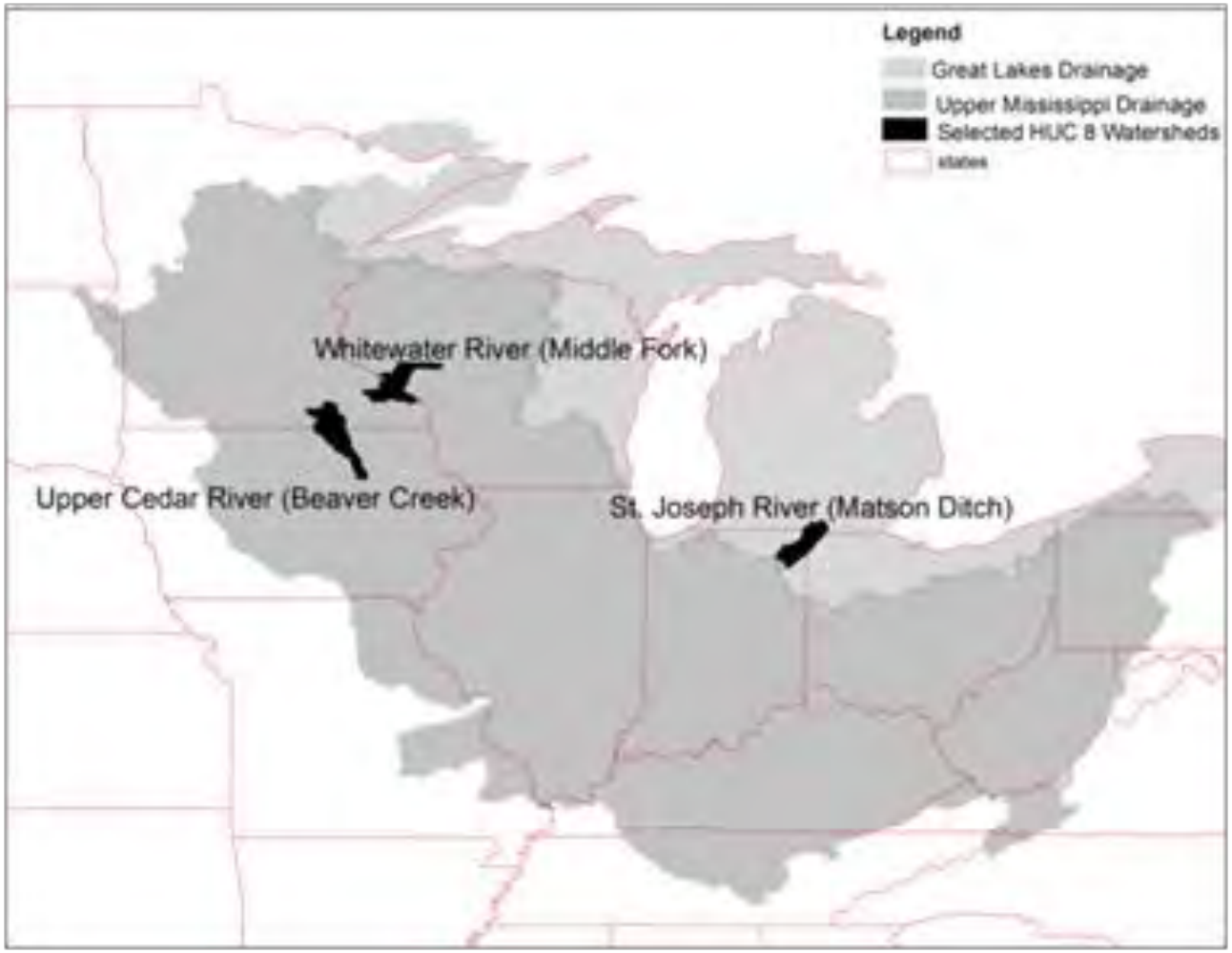
Denitrifying bioreactors

Two-stage drainage ditch

Nutrient removal wetlands

Practices to Manage Runoff & Water Quality

Three example watersheds:



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CONTROL, TRAP, and/or TREAT	TILE DRAINAGE	SURFACE RUNOFF
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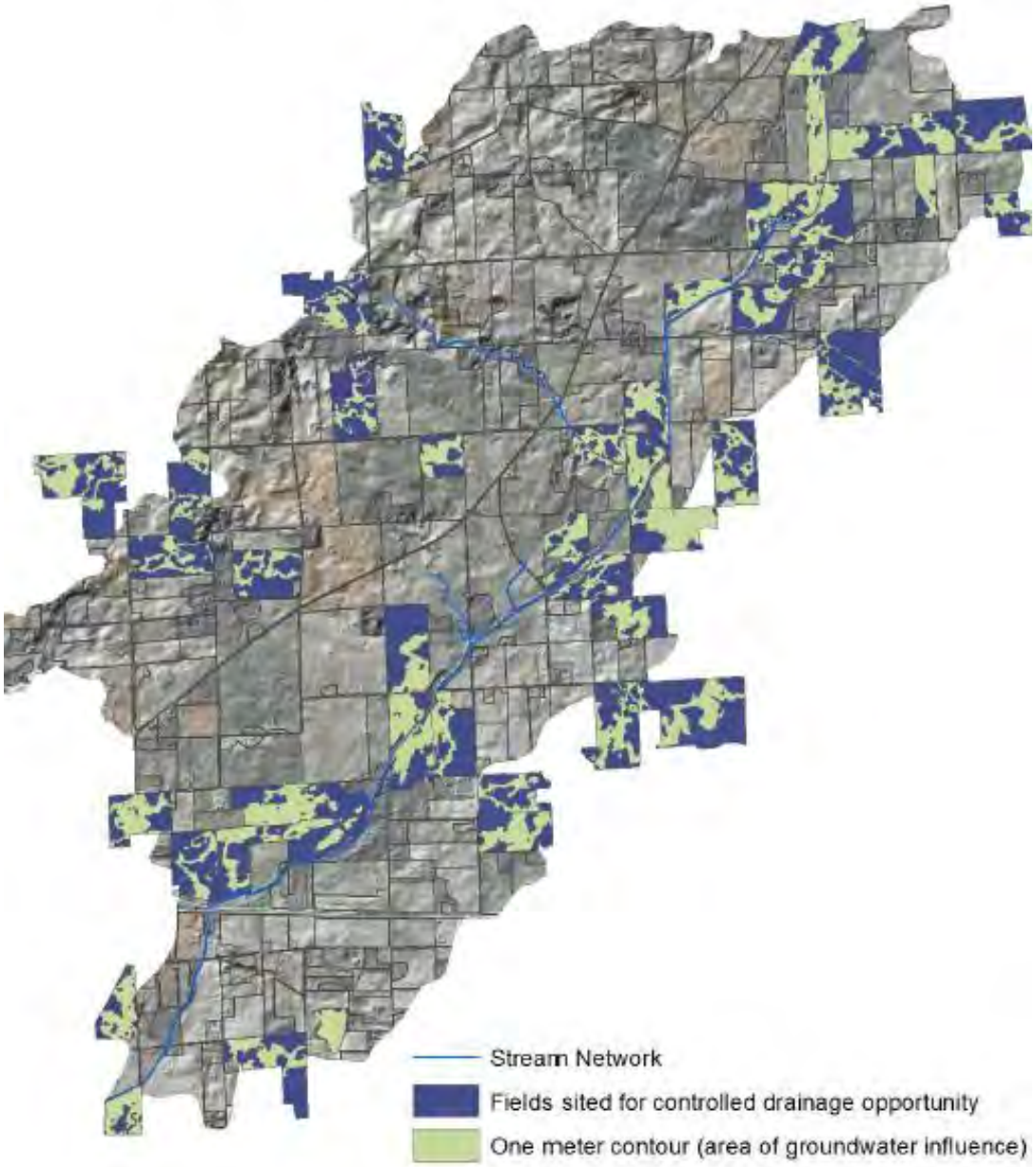
RIPARIAN ZONE Place/design practices for ecosystem function and nutrient removal		

Controlled Drainage Opportunities



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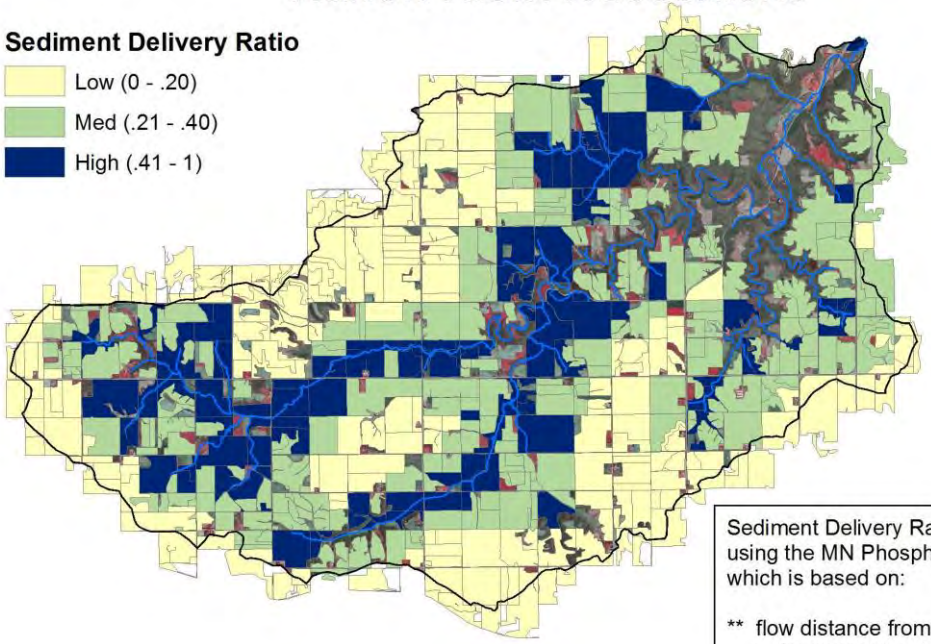
Assessments for prioritization and design of practices

Runoff Risk Assessment:
Prioritize fields where multiple erosion control practices are most needed

Close to stream?

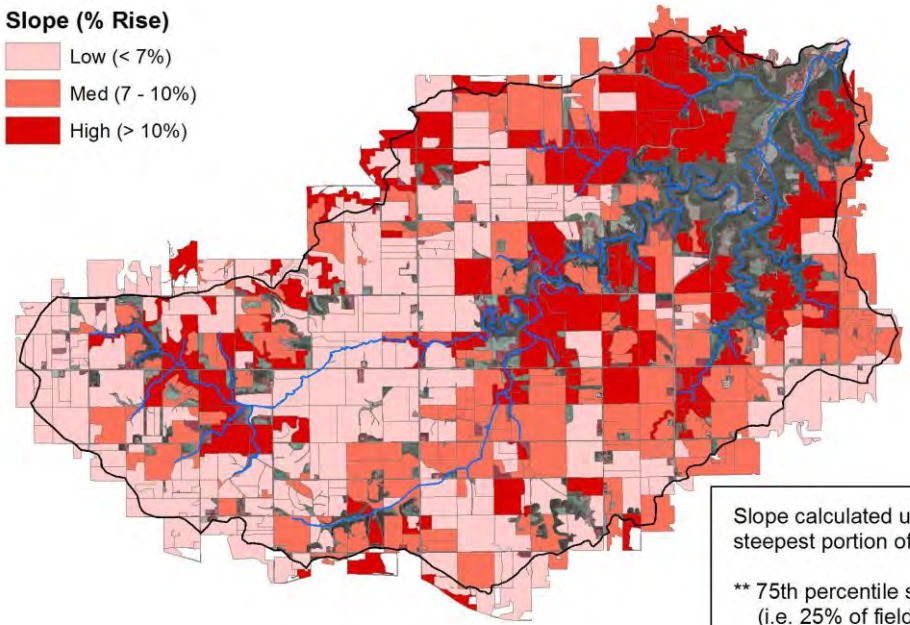
Slope steepness	Yes		No
H	A	B	C
M	B	C	
L	C		

Runoff Risk Assessment



Sediment Delivery Ratio calculated using the MN Phosphorus Index, which is based on:

** flow distance from edge of field to the nearest surface water



Slope calculated using the steepest portion of each field:

** 75th percentile slope value (i.e. 25% of field has slopes greater than this value)

Footslope landform regions

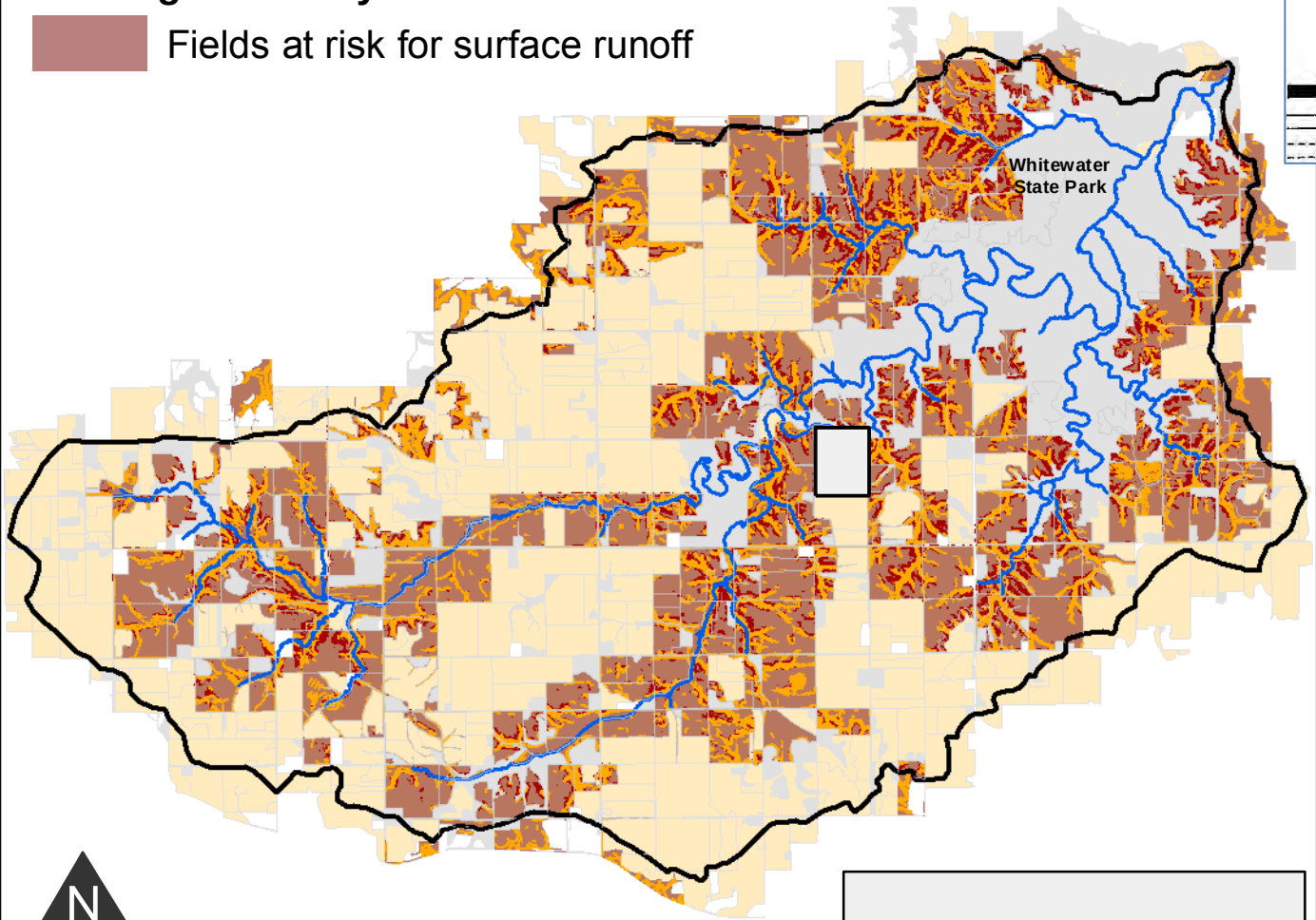
Landform characteristic

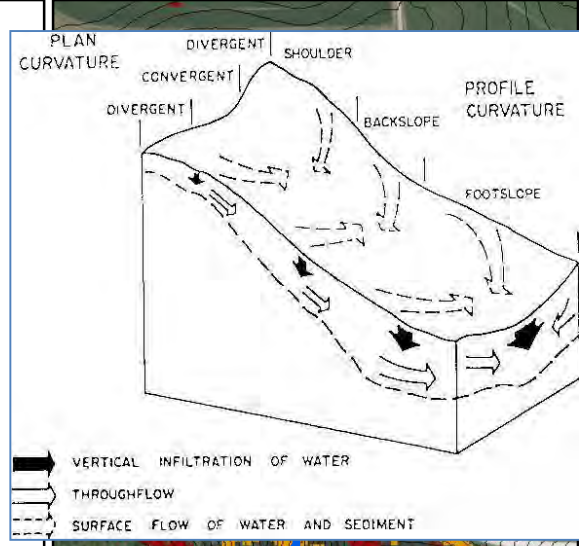
Footslopes

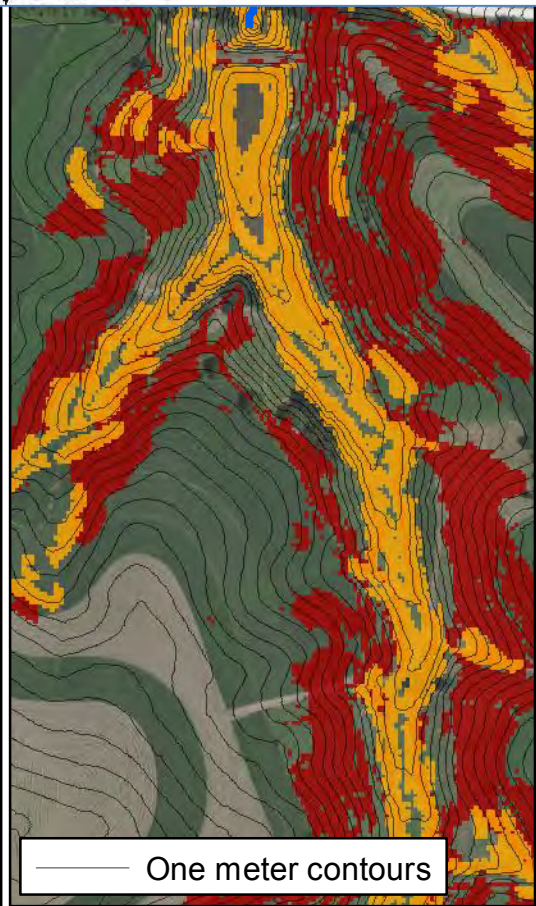
Slopes (10 - 15%)

Drainage Pathway

Fields at risk for surface runoff







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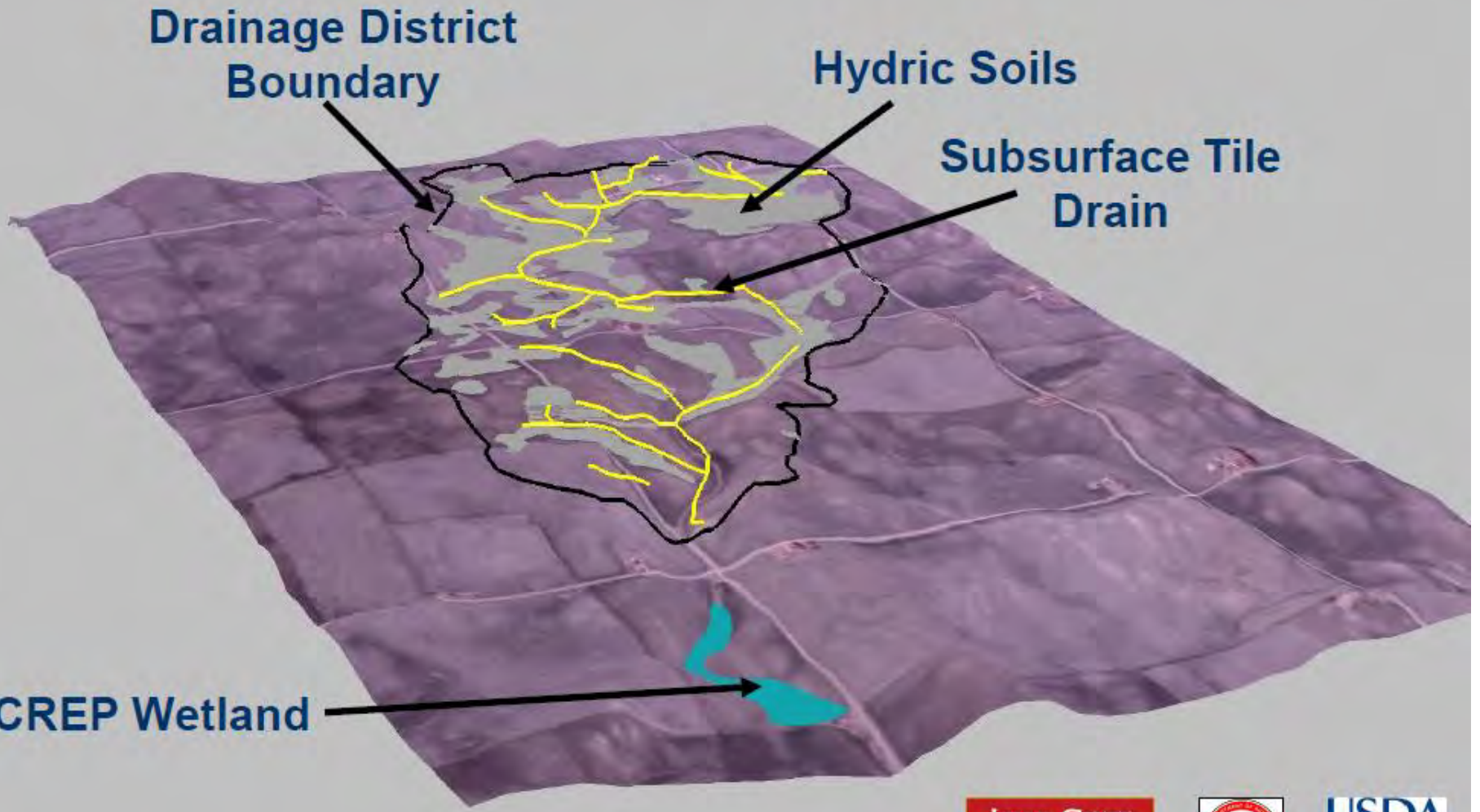
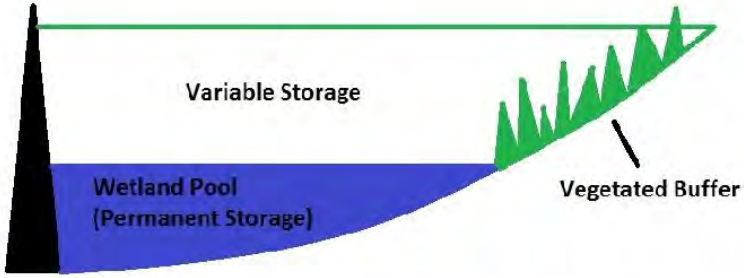
Slope steepness	Close to stream? Yes		No
H	A	B	C
M	B	C	
L	C		

Nutrient interception wetlands

Photo by IDALS-DSC

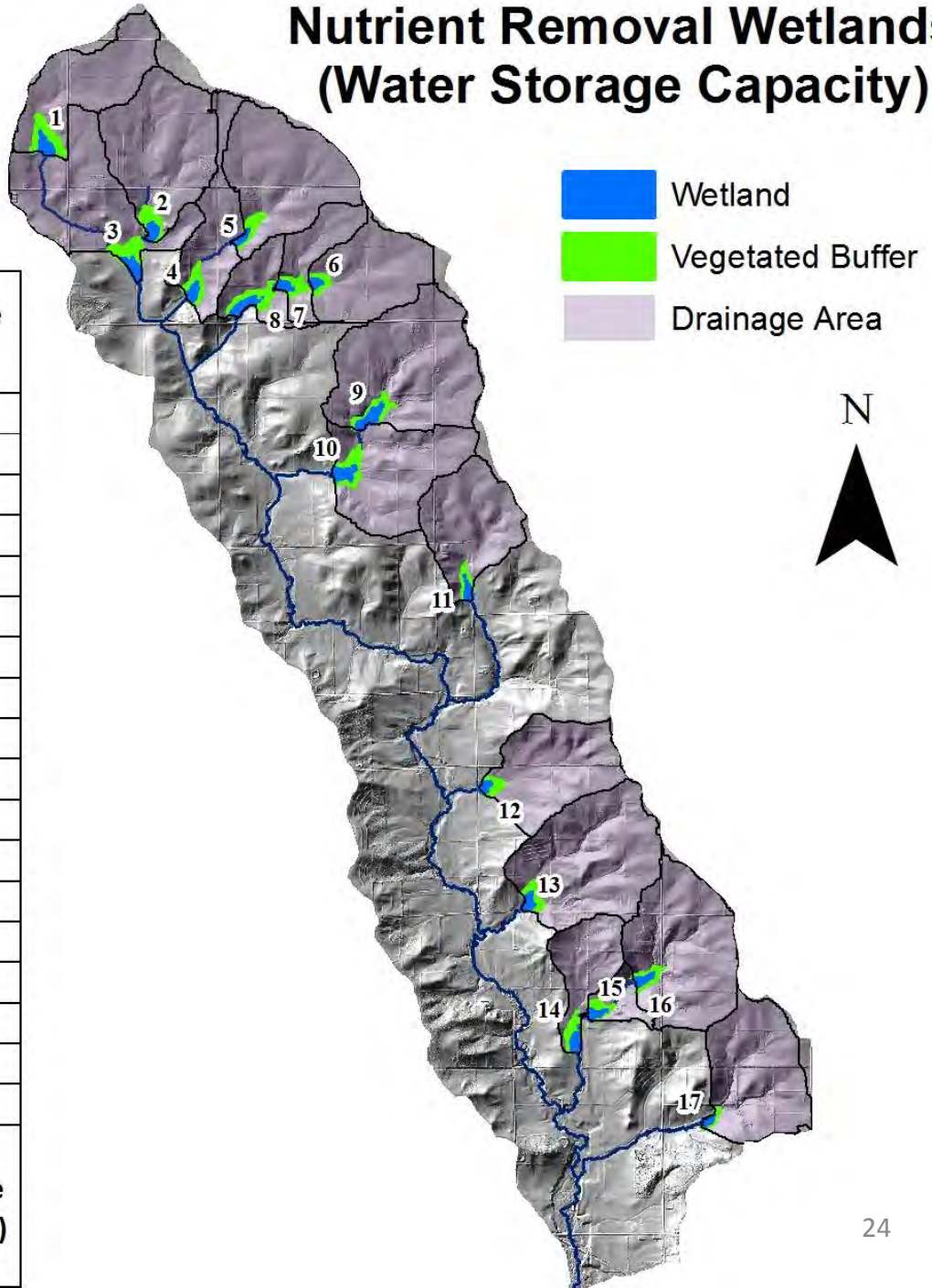
Iowa Conservation Reserve Enhancement Program





Wetland #	Permanent Storage (acre feet)	Variable Storage (acre feet)
1	7.32	66.33
2	3.98	43.31
3	8.35	64.49
4	4.22	35.10
5	3.73	25.72
6	2.11	23.13
7	4.90	32.00
8	10.94	57.73
9	16.49	50.62
10	8.14	54.56
11	5.43	23.08
12	3.31	26.86
13	7.47	33.39
14	6.94	40.98
15	5.34	25.17
16	4.97	25.08
17	3.82	15.22
TOTAL	96.18	642.77
AVERAGED ACROSS WATERSHED (11080.62 Acres)	.01 acre ft/acre (.12 acre in/acre)	.058 acre ft /acre (.69 acre in/ acre)

Nutrient Removal Wetlands (Water Storage Capacity)



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RIPARIAN ZONE Place/design practices for ecosystem function and nutrient removal		Design Types for **Riparian Buffers**: **CZ** Critical Zone -sensitive sites **MSB** Multi-Species Buffer **SSG** Stiff-Stemmed Grasses **DRV** Deep-Rooted Vegetation **SBS** Stream Bank Stability

Assessments for prioritization and design of practices

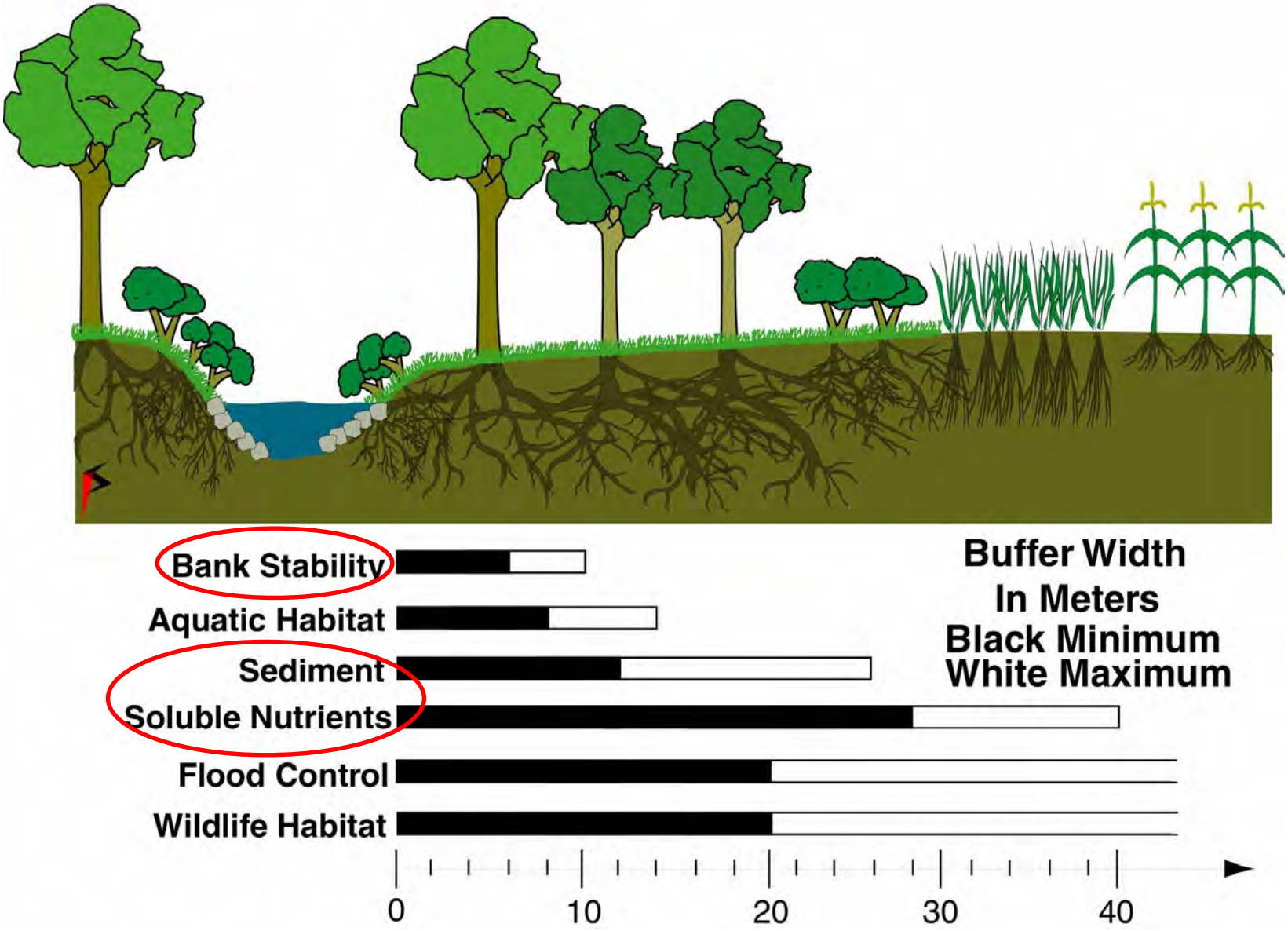
Runoff Risk Assessment: Prioritize fields where multiple erosion control practices are most needed

Slope steepness	Close to stream? Yes		No
H	A	B	C
M	B	C	
L	C		

Riparian Assessment: Identify riparian function by stream reach

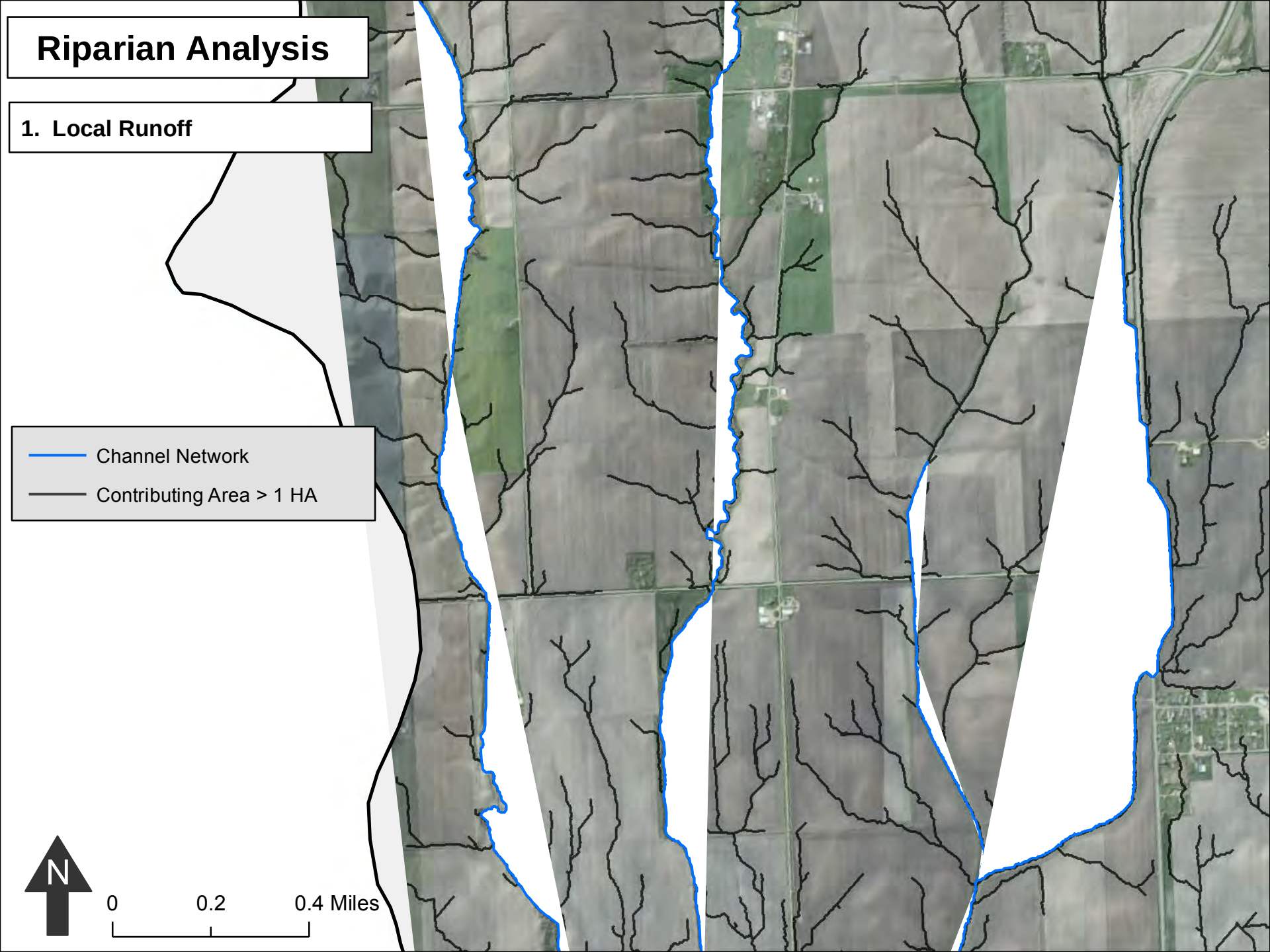
Runoff delivery	Shallow water table? Yes		No
H	CZ	MSB	SSG
M	MSB	MSB	SSG
L	DRV	DRV	SBS

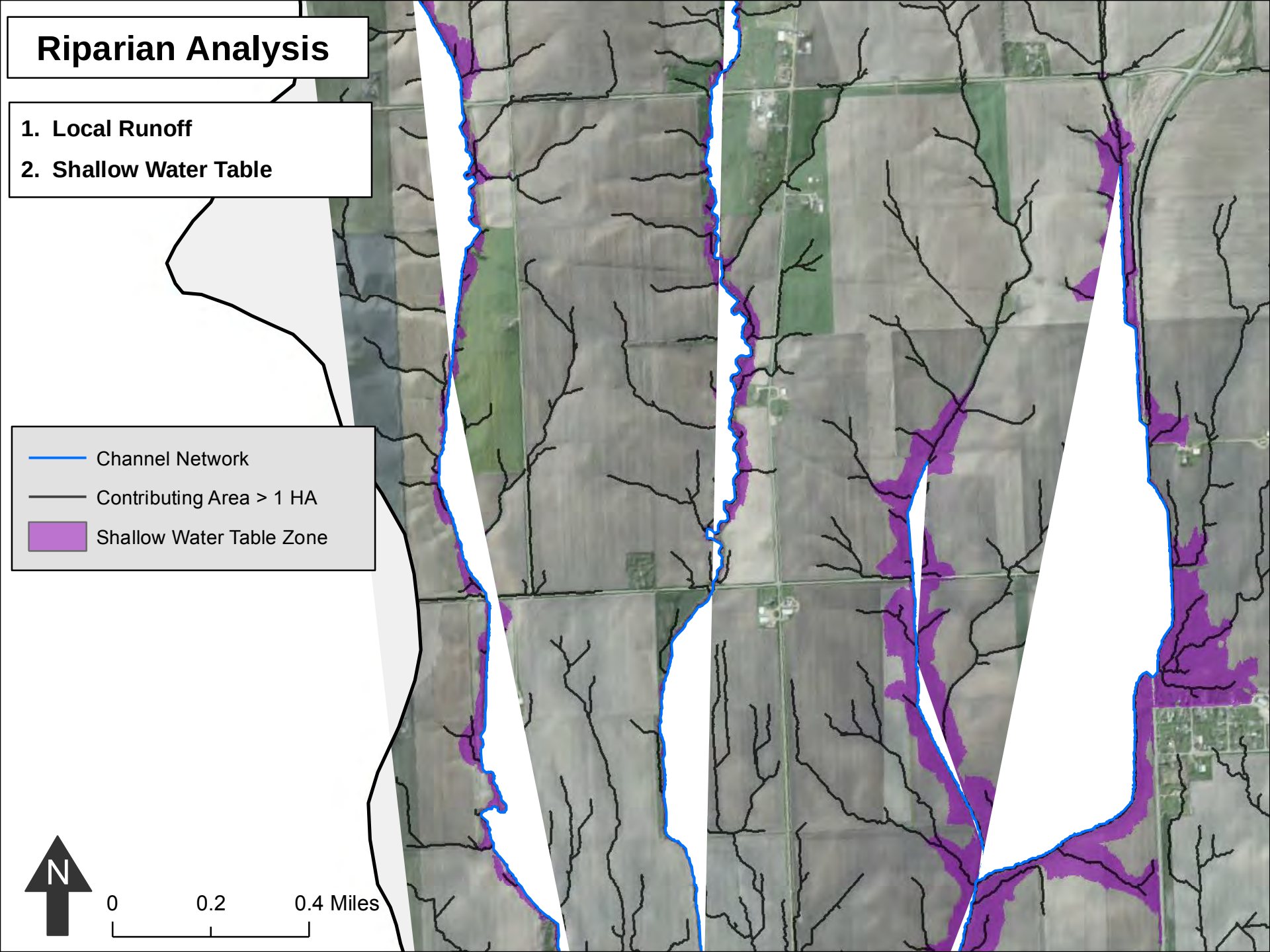
Potential Riparian Functions Depend on Landscape Attributes and May Be Achieved at Varying Buffer Widths

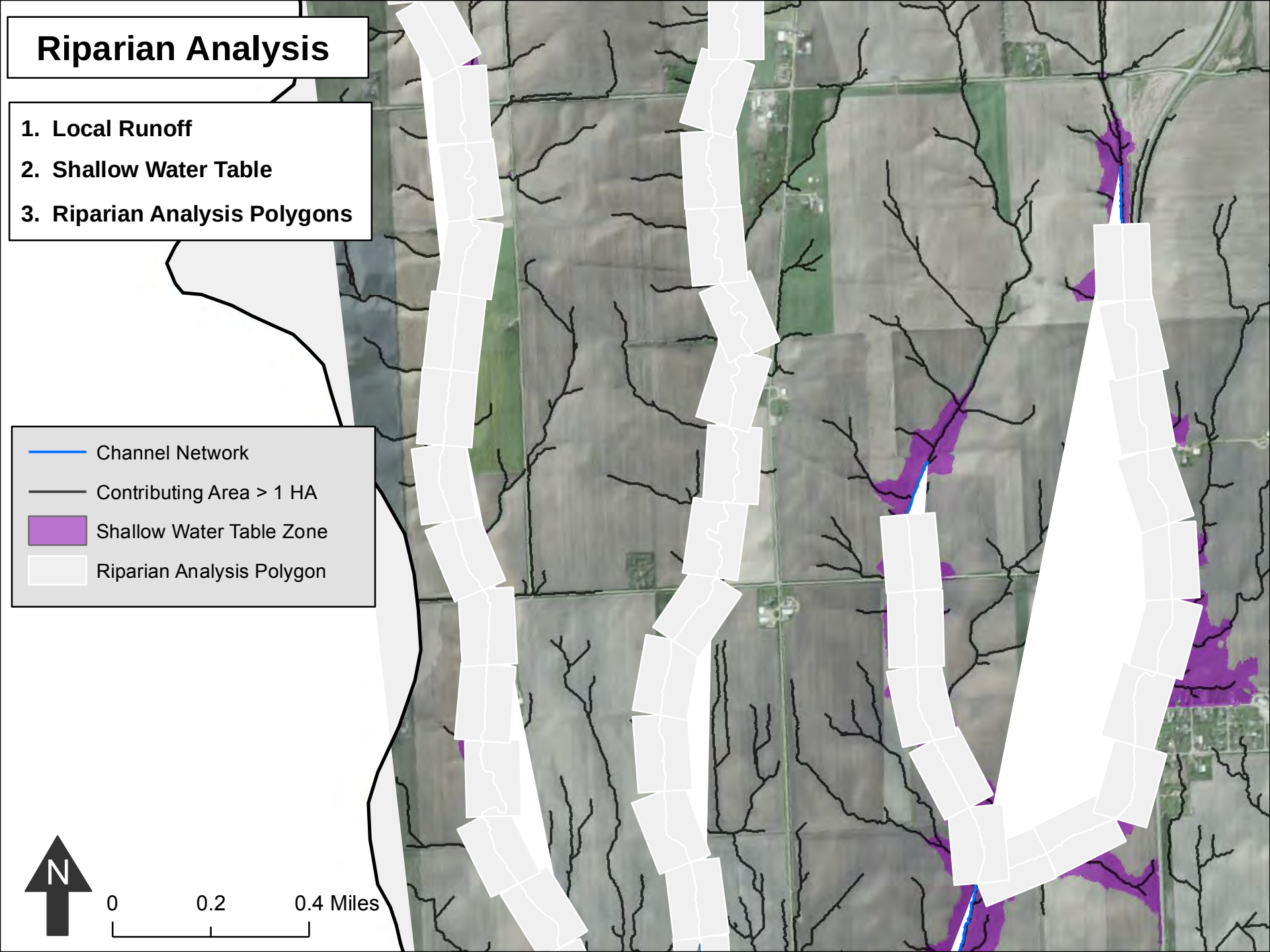


Riparian Analysis

1. Local Runoff

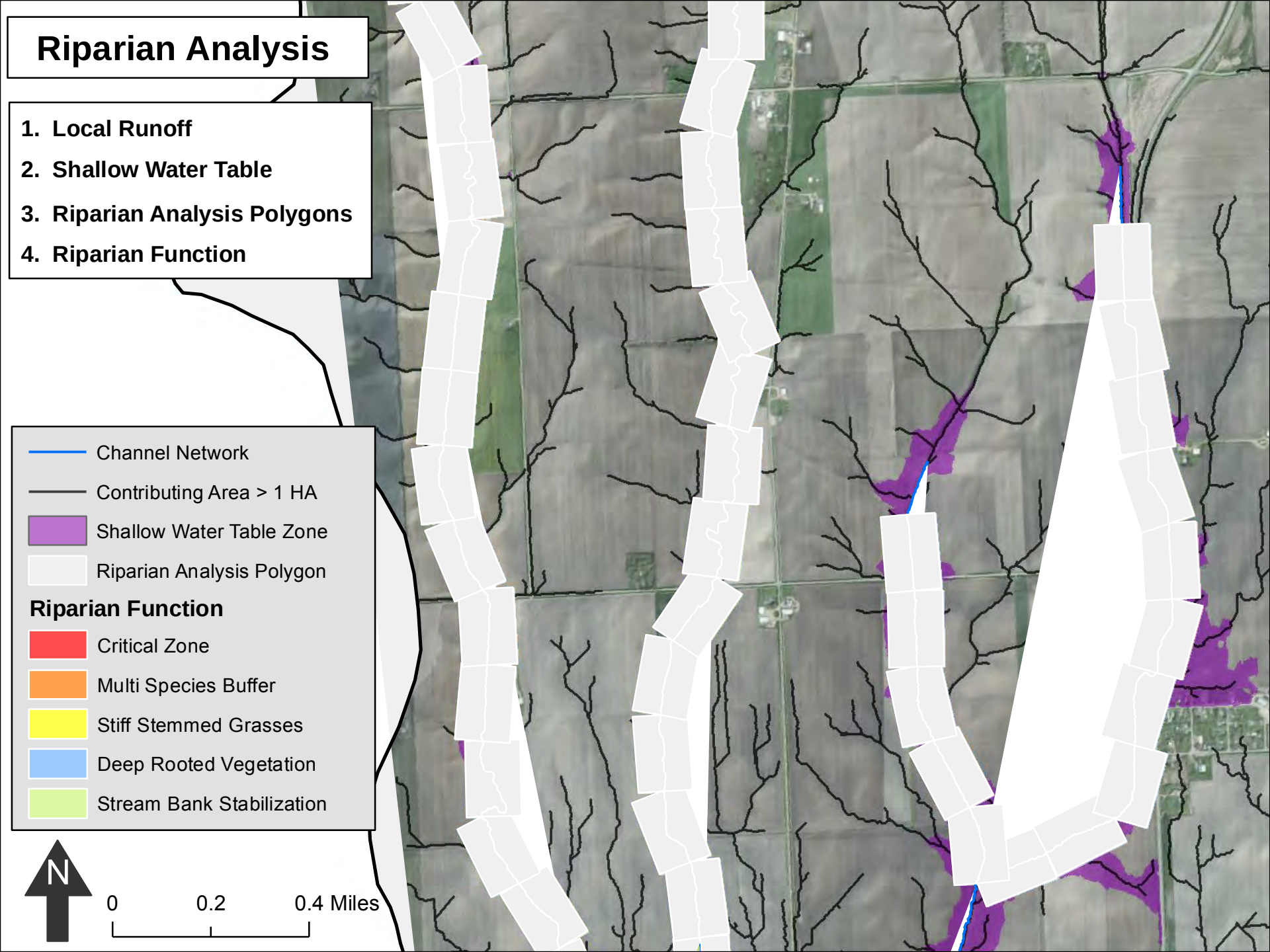



Riparian Analysis
1. Local Runoff
2. Shallow Water Table
Channel Network
Contributing Area > 1 HA
Shallow Water Table Zone
N
0
0.2
0.4 Miles


Riparian Analysis
1. Local Runoff
2. Shallow Water Table
3. Riparian Analysis Polygons
Channel Network
Contributing Area > 1 HA
Shallow Water Table Zone
Riparian Analysis Polygon
N
0
0.2
0.4 Miles

Riparian Analysis

1. Local Runoff
2. Shallow Water Table
3. Riparian Analysis Polygons
4. Riparian Function



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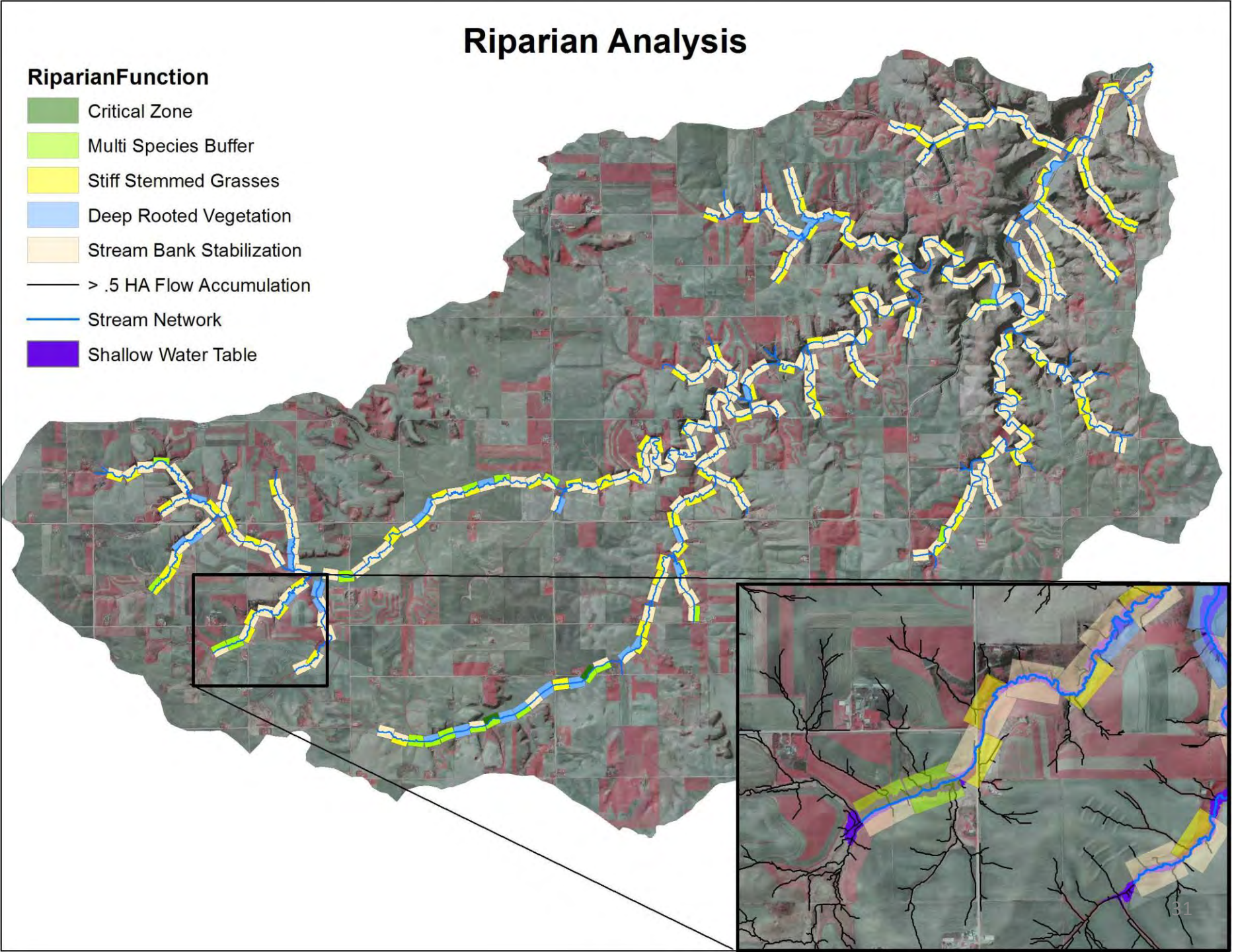

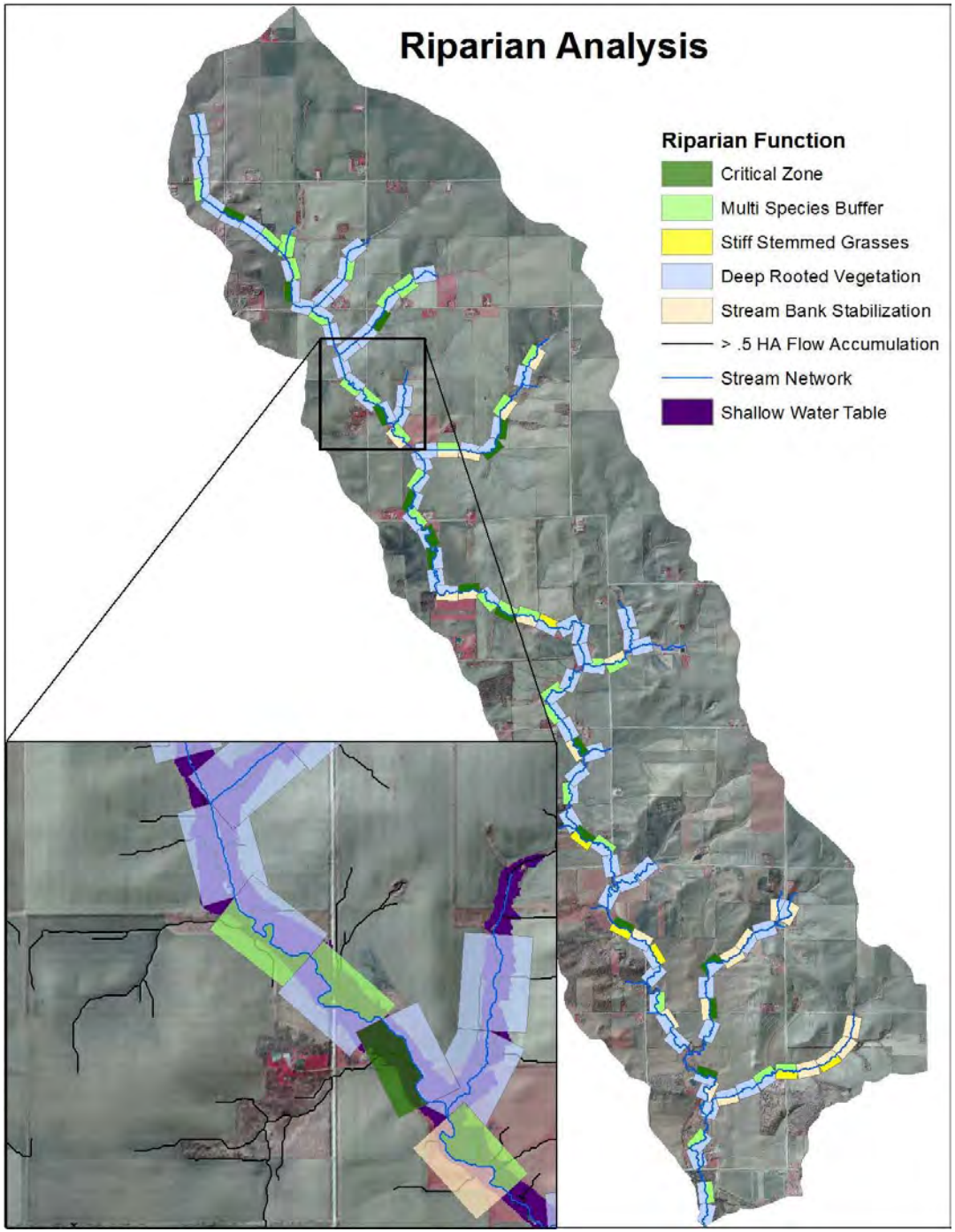
Riparian Analysis
Riparian Function
Critical Zone
Multi Species Buffer
Stiff Stemmed Grasses
Deep Rooted Vegetation
Stream Bank Stabilization
> .5 HA Flow Accumulation
Stream Network
Shallow Water Table

Shallow water table riparian zones – upper watershed

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Downstream/ In-stream: River restoration (e.g., pool-riffle structures, re-meandering, oxbow rehabilitation)

APPLICATION: Scenario Development/ stakeholder feedback/ implement/ monitor/ adapt

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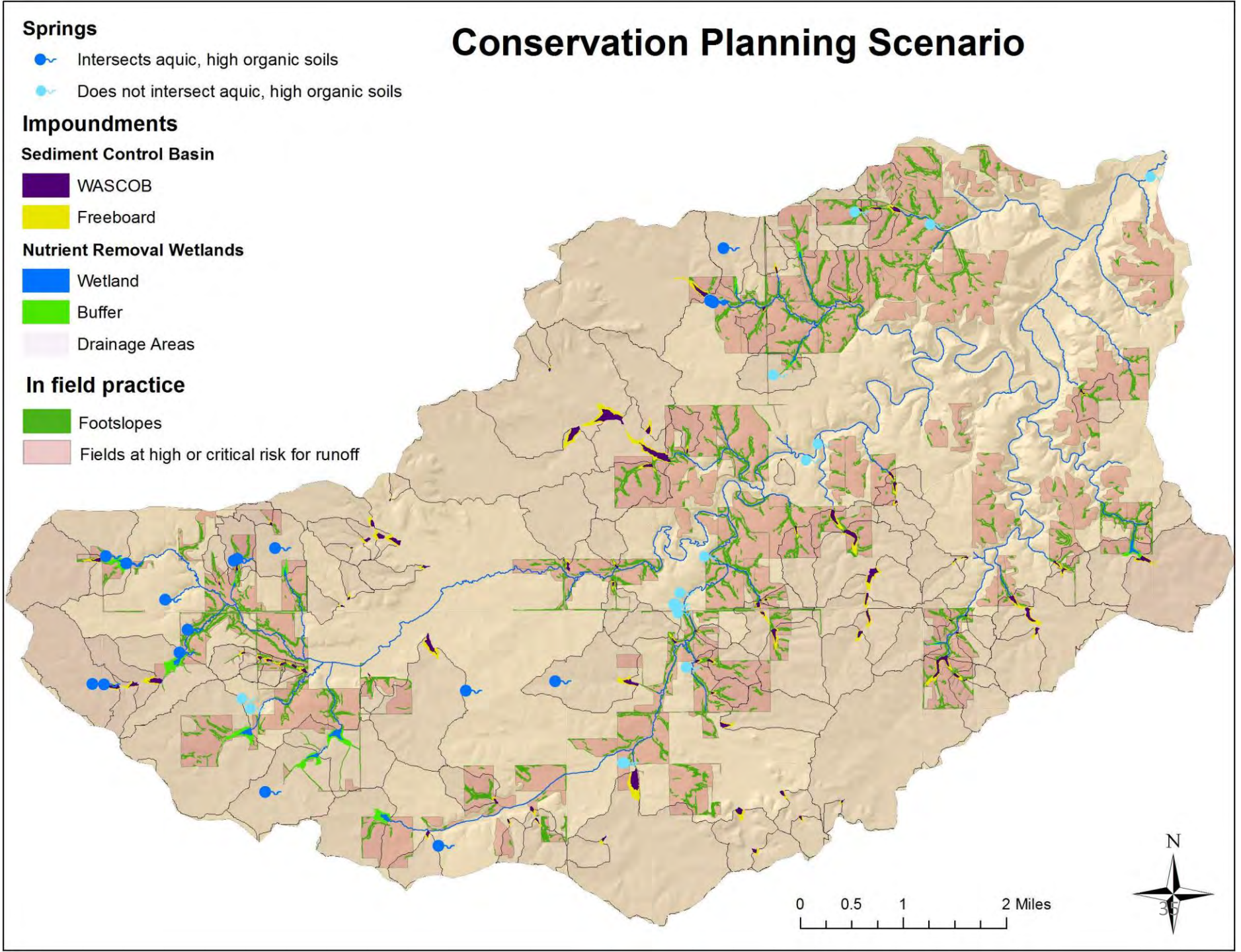
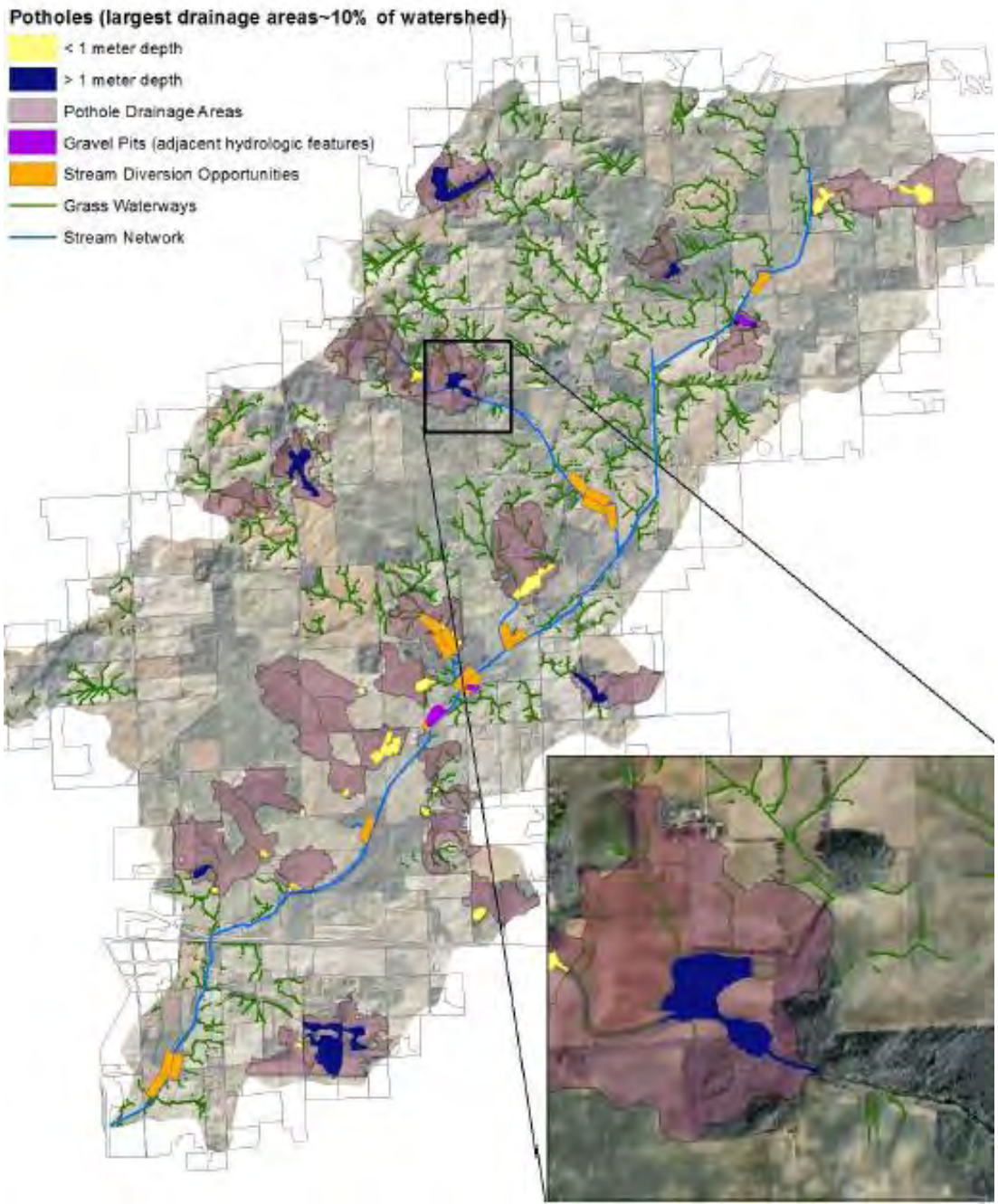
L	DRV	DRV	SBS

Conservation Planning Scenario

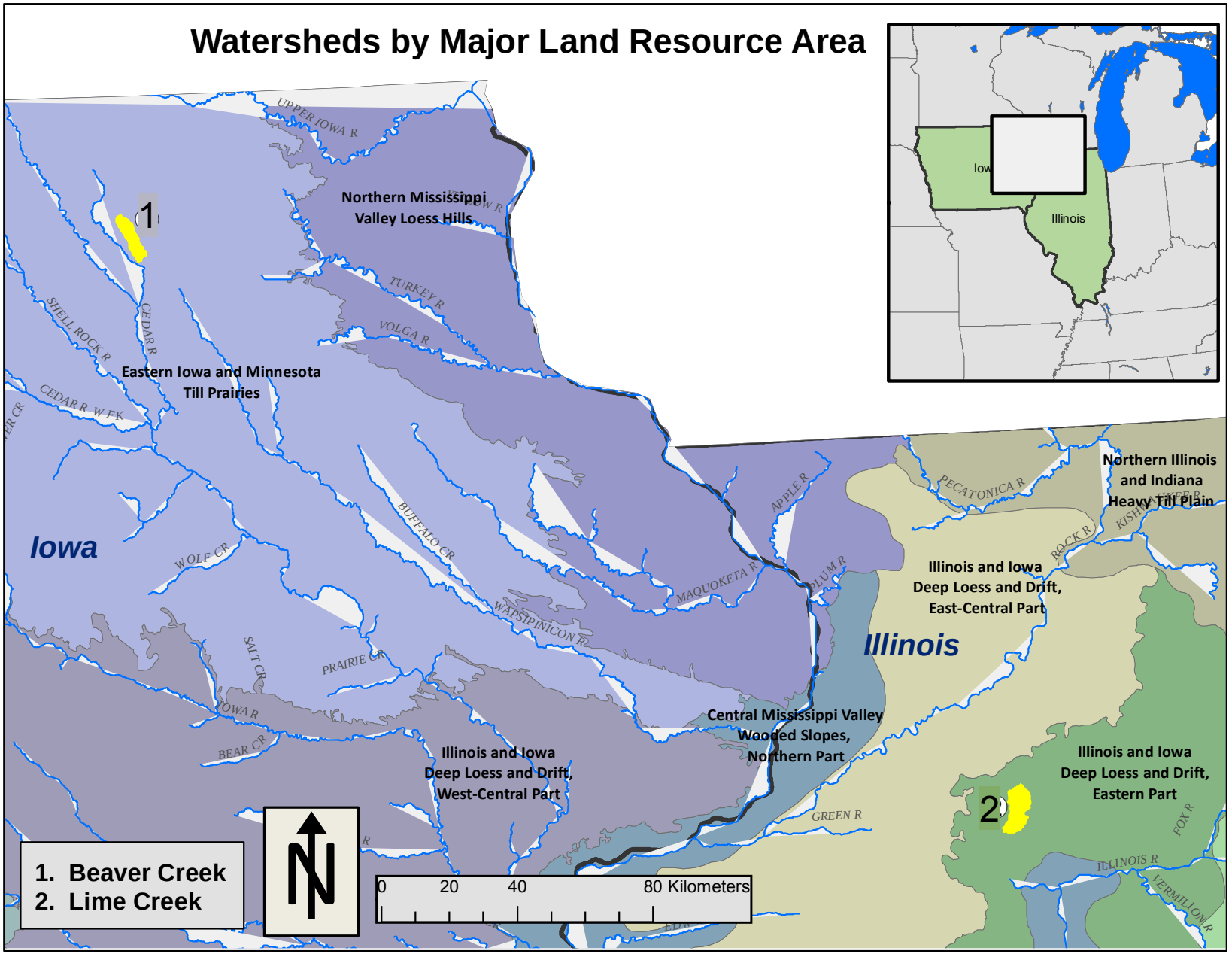


Conservation Planning Scenario

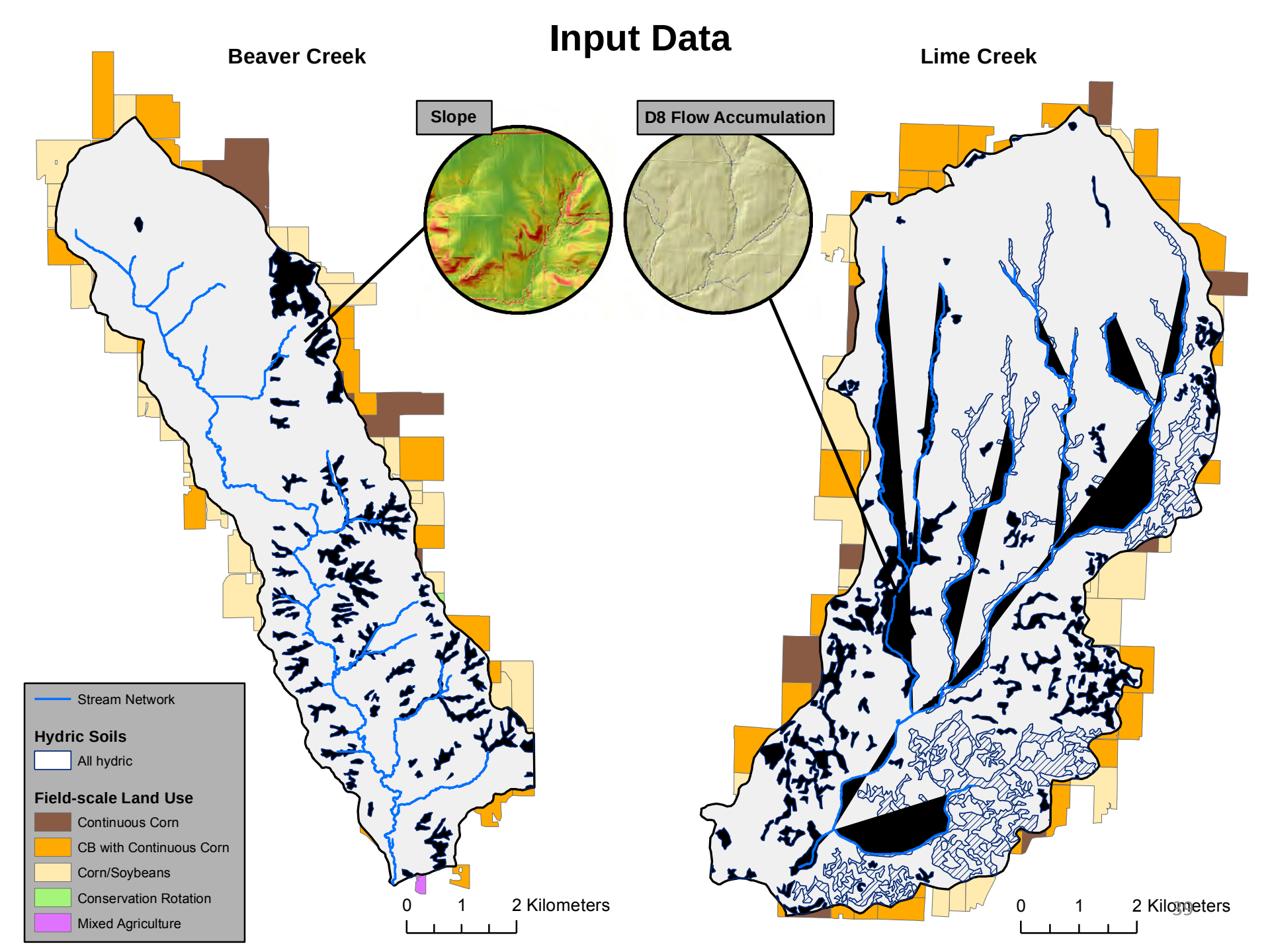


Conservation Planning Scenarios

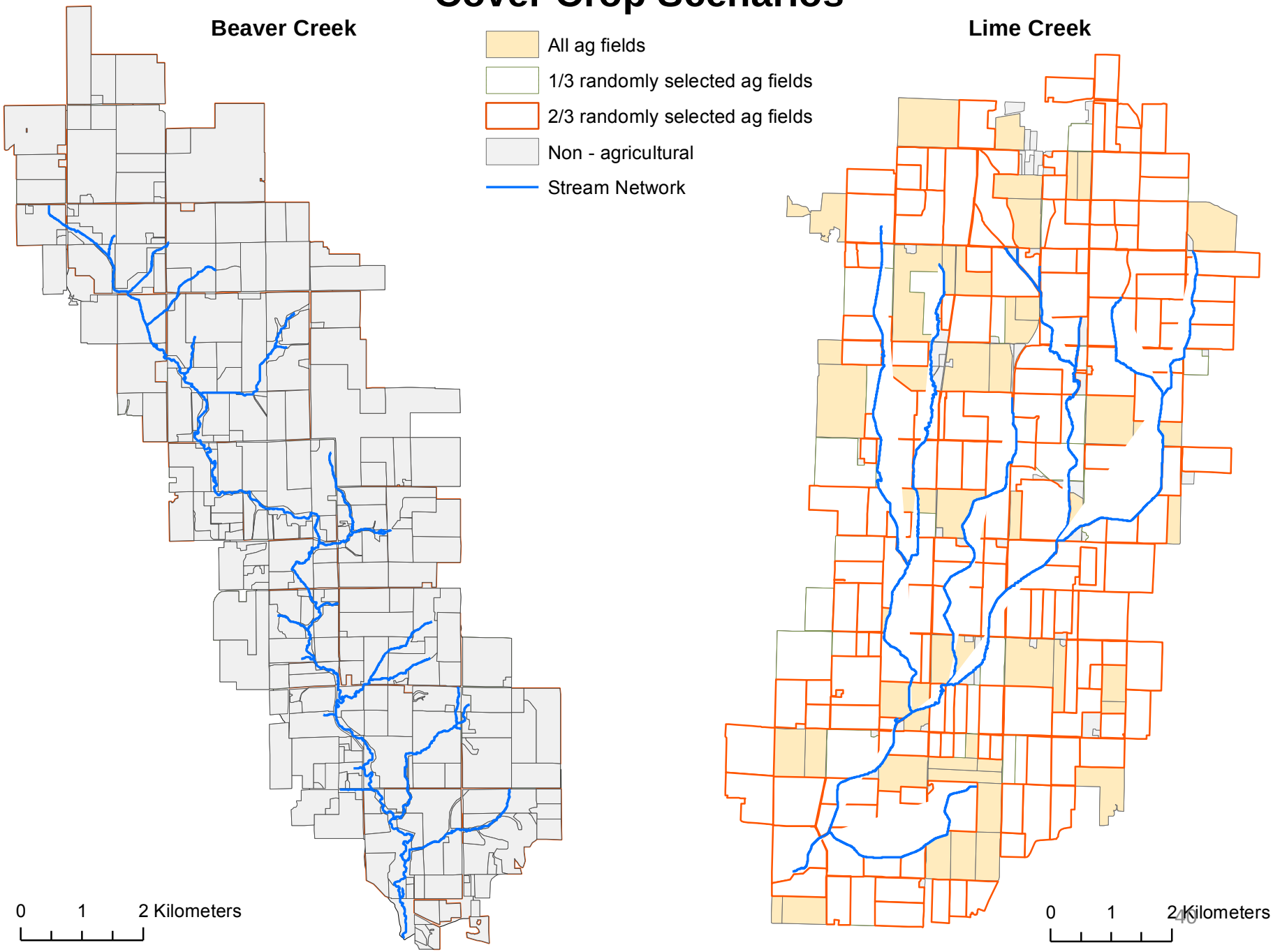
How do we identify planning alternatives that can progress towards (or meet) nutrient reduction goals?

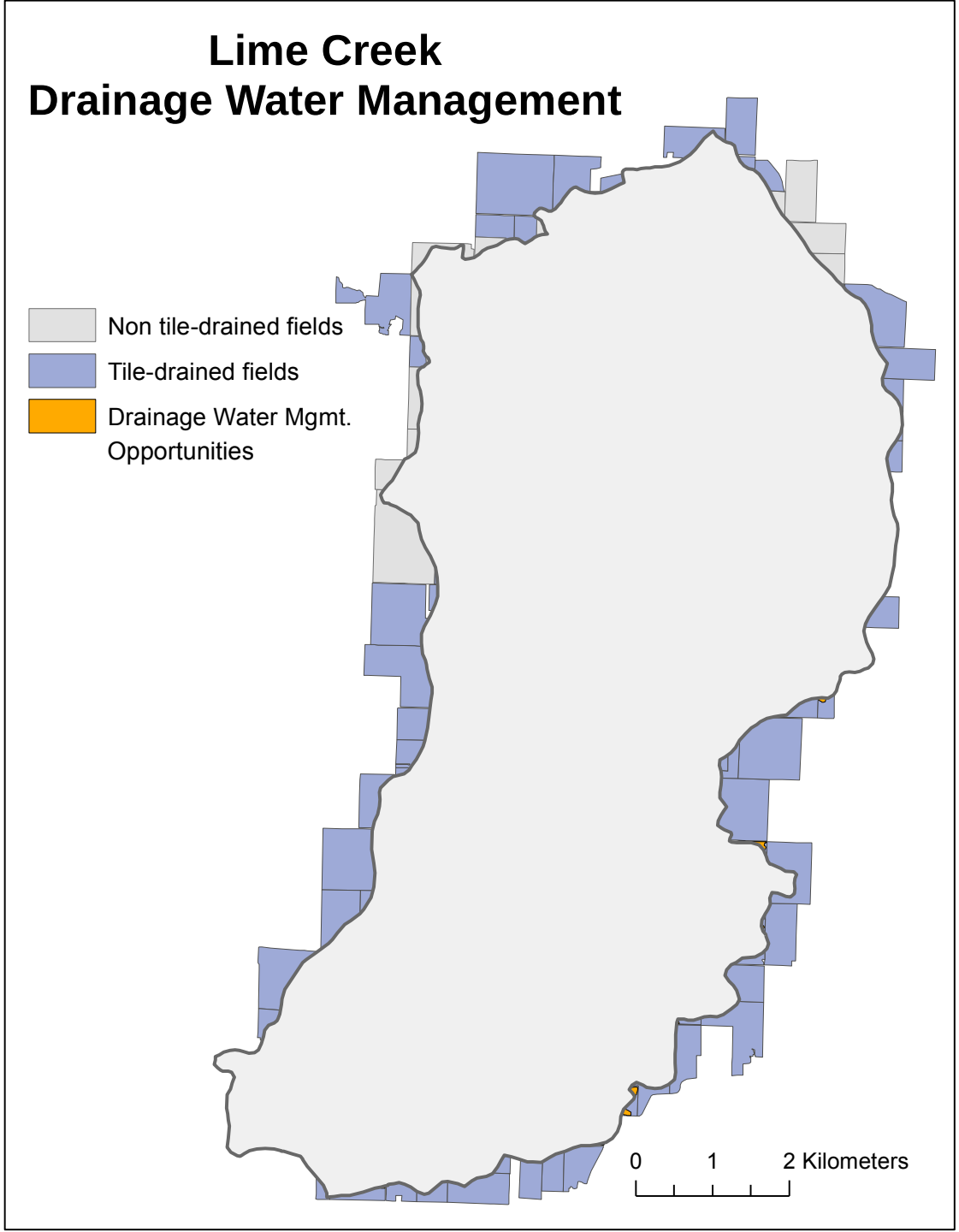

Watersheds by Major Land Resource Area
Iowa
Illinois
Northern Mississippi Valley Loess Hills
Eastern Iowa and Minnesota Till Prairies
Illinois and Iowa Deep Loess and Drift, West-Central Part
Central Mississippi Valley Wooded Slopes, Northern Part
Illinois and Iowa Deep Loess and Drift, East-Central Part
Northern Illinois and Indiana Heavy Till Plain
Illinois and Iowa Deep Loess and Drift, Eastern Part
1
2
1. Beaver Creek
2. Lime Creek
0 20 40 80 Kilometers
UPPER IOWA R
TURKEY R
VOLGA R
SHEIL ROCK R
CEDAR R
CEDAR R W FK
WOLF CR
BUFFALO CR
APPLE R
MAQUOKETA R
PLUM R
WAPSIPINICON R
SALT CR
PRAIRIE CR
IOWA R
BEAR CR
GREEN R
PECATONICA R
ROCK R
FOX R
ILLINOIS R
VERMILION R

Input Data

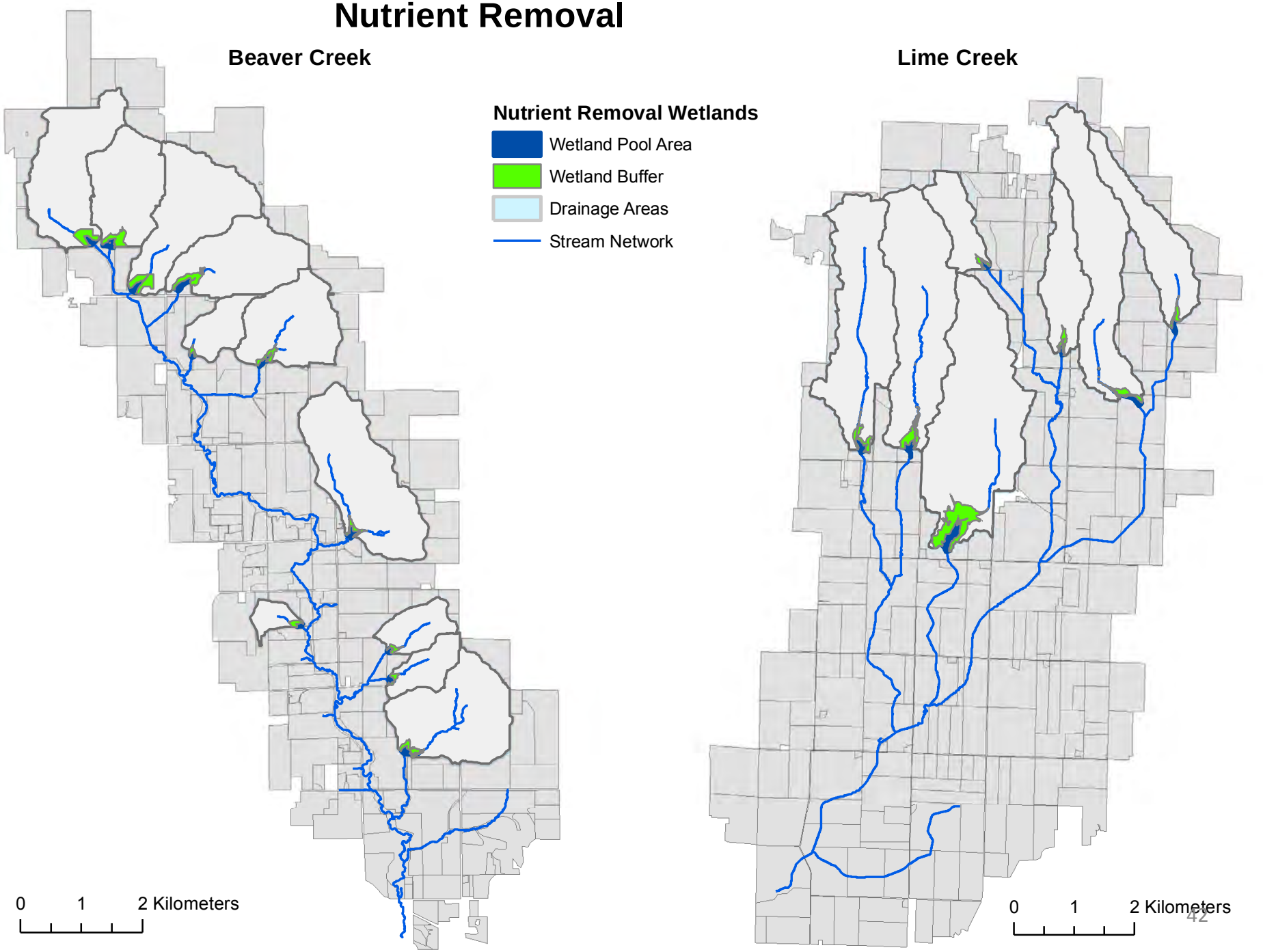

Beaver Creek
Slope
D8 Flow Accumulation
Lime Creek
Stream Network
Hydric Soils
All hydric
Field-scale Land Use
Continuous Corn
CB with Continuous Corn
Corn/Soybeans
Conservation Rotation
Mixed Agriculture
0 1 2 Kilometers
0 1 2 Kilometers

Cover Crop Scenarios

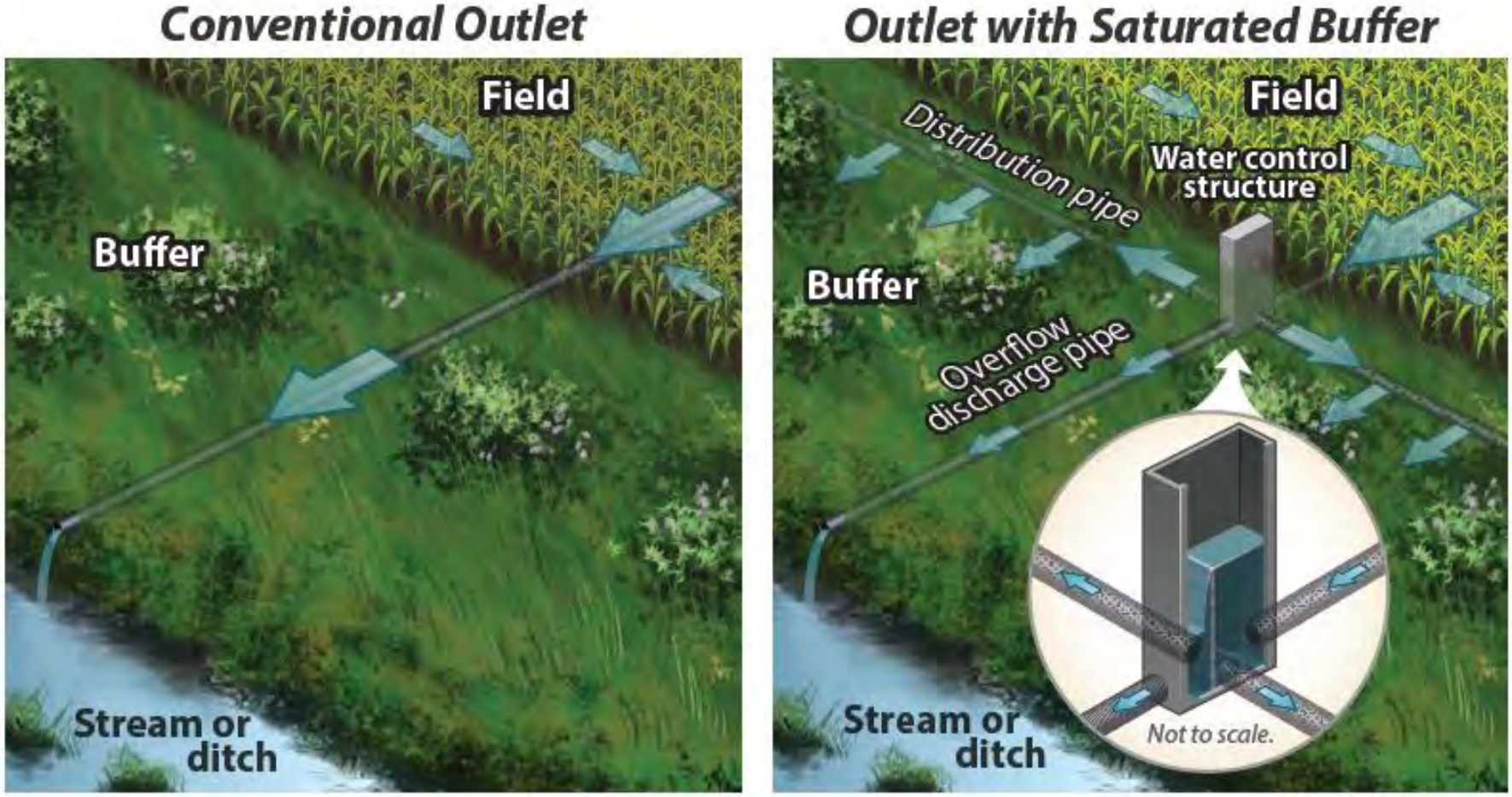


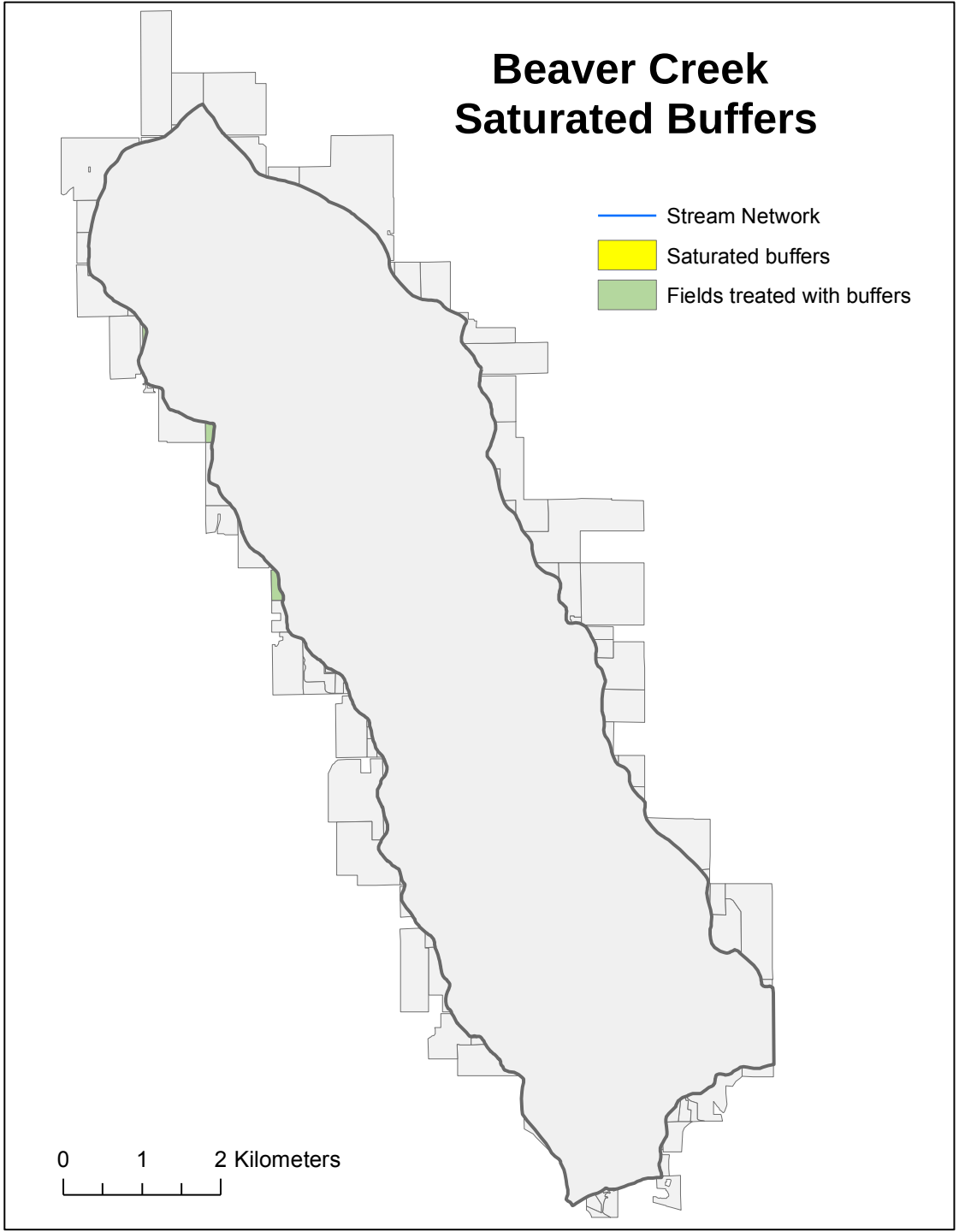

Lime Creek
Drainage Water Management
Non tile-drained fields
Tile-drained fields
Drainage Water Mgmt. Opportunities
0
1
2 Kilometers

Nutrient Removal



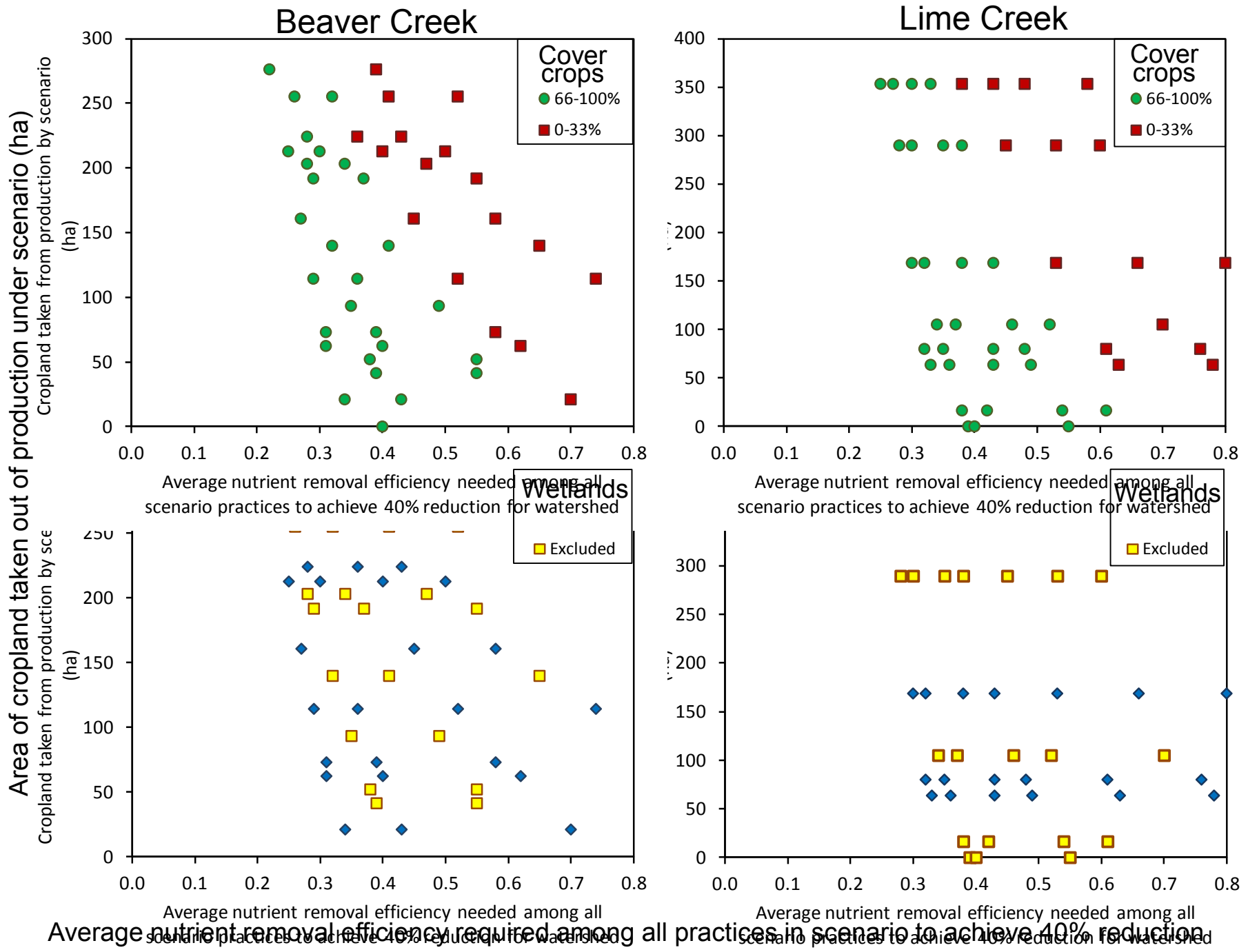
Inclusion of novel practices – e.g., saturated riparian buffer




Beaver Creek
Saturated Buffers
Stream Network
Saturated buffers
Fields treated with buffers
0
1
2 Kilometers

Developing and Evaluating Conservation Planning Scenarios

1. Select many different combinations of practices, including soil improvement (cover crops), in-field (controlled drainage, grassed waterways), edge-of field (wetlands), and riparian practices (saturated buffers).
2. Set up a spreadsheet in which each row represents a field, and columns represent the field size, relative impact of crop rotation on nutrient loss, and presence of absence of each practice within or below each field.
3. Calculate the average nutrient removal efficiency required among all the practices in the scenario to meet a nutrient reduction goal.
4. Plot the average against the amount of land taken out of crop production under each scenario.


Beaver Creek
Lime Creek
Wetlands
Wetlands
Cover crops
66-100%
0-33%
Excluded
Area of cropland taken out of production under scenario (ha)
Cropland taken from production by scenario (ha)
Average nutrient removal efficiency needed among all scenario practices to achieve 40% reduction for watershed
Average nutrient removal efficiency required among all practices in scenario to achieve 40% reduction

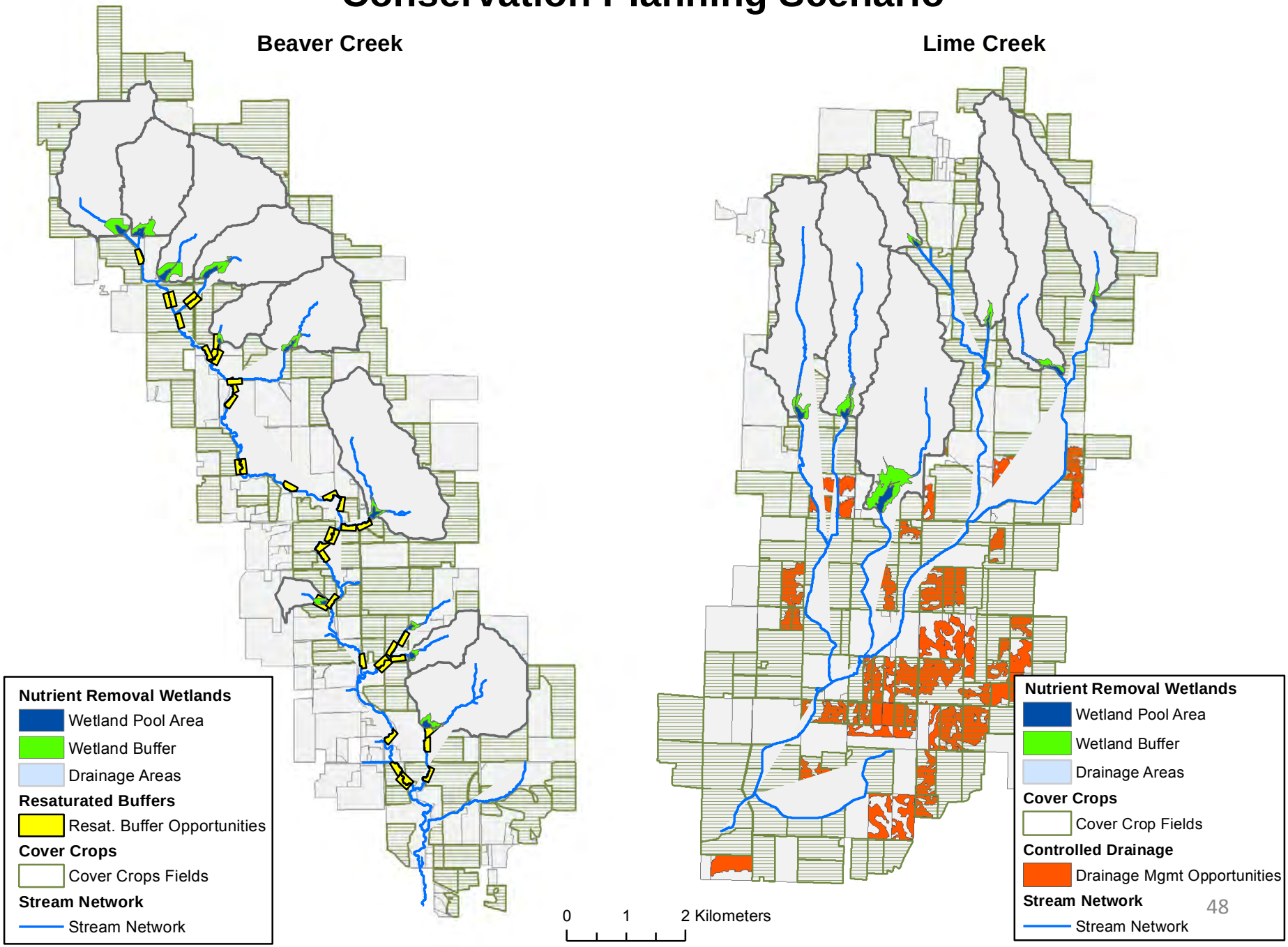
Effectiveness of Practices for Nitrogen Reduction- Results of Literature Review

	Practice	% Nitrate-N Reduction [Average (Std. Dev.)]
Crop Rotation / Land Use	**Cover Crops**	**31 (29)**
	Perennial – Land retirement	85 (9)
	Living Mulches	41 (16)
	Extended Rotations	42 (12)
Drainage Management	**Controlled Drainage**	**33 (32)***
	Shallow Drainage	32 (15)*
	Bioreactors (assign to sat. buffers)	**43 (21)**
Downstream	**Wetlands**	**52**
	Buffers	91 (20)**

*Load reduction not concentration reduction

**Concentration reduction of that water interacts with active zone below the buffer

Conservation Planning Scenario



ACPF Summary:

- Aim is to develop a customized planning resource for HUC12 watersheds. Input data required are widely available in the Midwest.
- Addresses tile drainage and runoff pathways, while stressing the importance of soil health for conservation success.
- Suggests possible beneficial locations for different types of practices placed in fields, at field edges, and in riparian zones.
- Includes common types of practices; can include new practices if placement criteria can be defined/applied to input data.
- Planning scenarios can be generated from the results and compared/evaluated in a simple way without additional input.
- No recommendations are made. The aim is to develop a planning resource, not a plan. Actual watershed planning is inherently a local consultative process involving landowners.

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Jill Kostel, The Wetlands Initiative

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Further information:

Tomer, M.D., S.A. Porter, D.E. James, K.M.B. Boomer, J.A. Kostel, and E. McLellan. 2013. Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. Journal of Soil and Water Conservation. 68(5):113A-120A.

Available at: http://www.jswconline.org/content/68/5/113A.full.pdf+html

Additional papers in review.